US005402469A

United States Patent [19]

Hopper et al.

[11] Patent Number: 5,402,469

[45] Date of Patent: Mar. 28, 1995

[54] CARRIER LOCATING SYSTEM

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[21] Appl. No.: **973,264**

[22] Filed: **Nov. 9, 1992**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 590,012, Sep. 28, 1990, abandoned.

[51] Int. Cl.[6] H04M 11/00

[52] U.S. Cl. 379/93; 379/201; 379/211; 340/825.54

[58] Field of Search 379/201, 210, 211, 196, 379/93–96; 358/825.44, 825.54, 825.55

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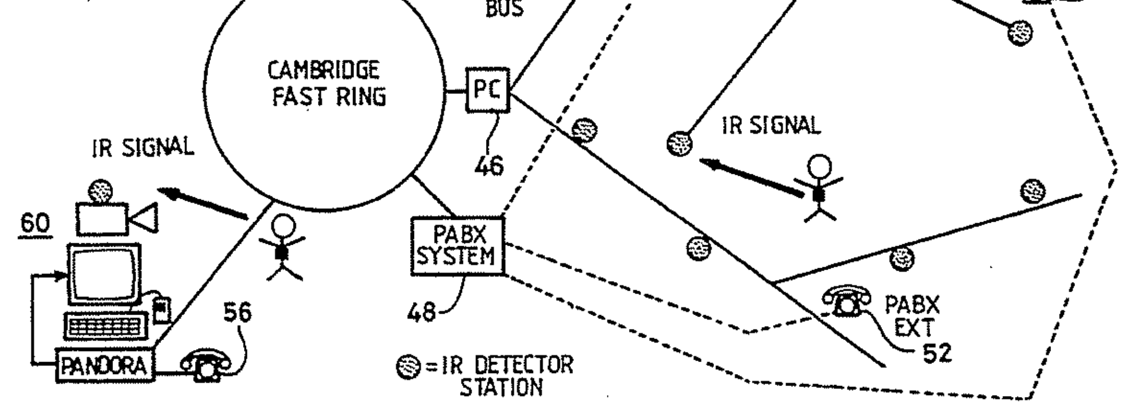
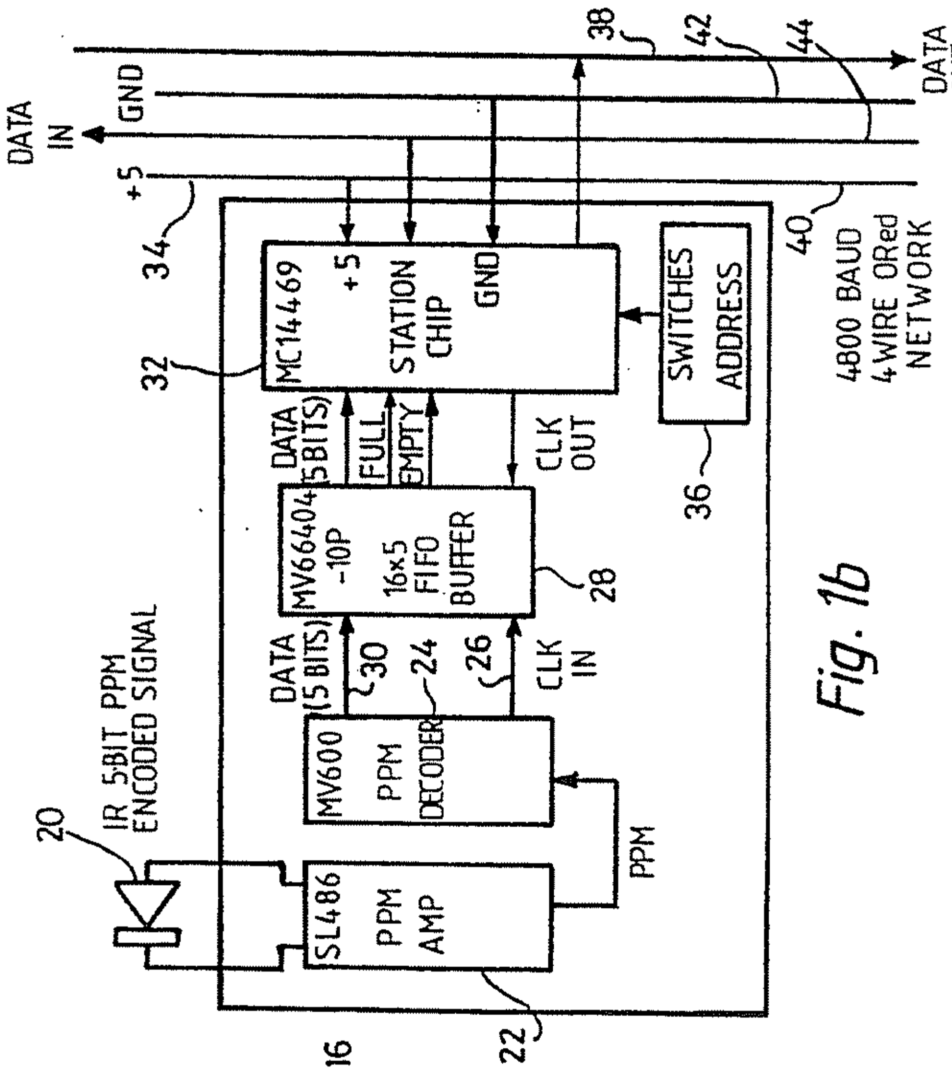
Primary Examiner—Wing F. Chan
Attorney, Agent, or Firm—Lee, Mann, Smith, McWilliams, Sweeney & Ohlson

[57] **ABSTRACT**

A system for locating any mobile body or a plurality thereof within a predetermined environment, wherein each mobile body carries a transmitter (10 to 18), each transmitter producing a unique identifying signal, and a plurality of receivers (20 to 32) located in a corresponding plurality of defined regions in the environment, each receiver incorporating a FIFO buffer memory (28) into which carrier identifying data is inserted and a controller for interrogating the receiver means in turn to link the identification data with location data.

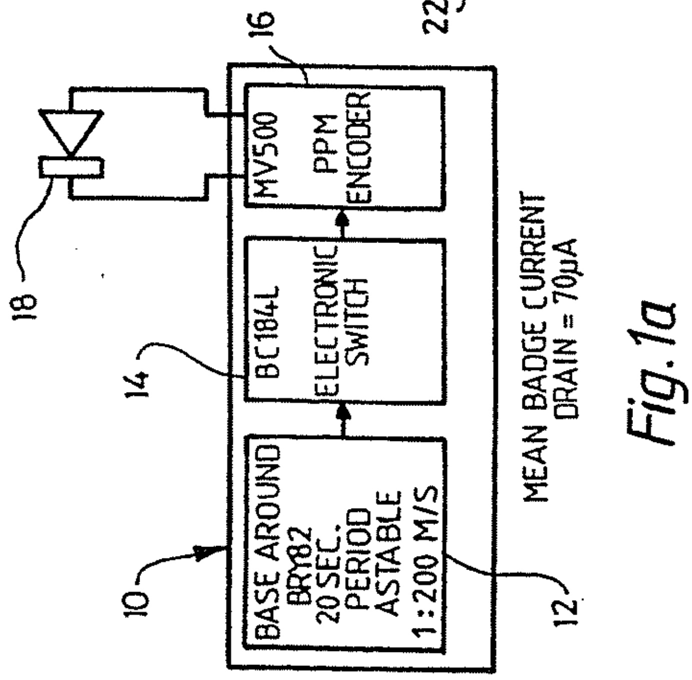
15 Claims, 2 Drawing Sheets





DATA IN
GND
+5
DATA OUT
38
42
44
34
40
4800 BAUD 4WIRE ORed NETWORK
32
MC14469
+5
STATION CHIP
GND
SWITCHES ADDRESS
36
DATA (5BITS)
FULL
EMPTY
CLK OUT
MV66404-10P
16x5 FIFO BUFFER
28
DATA (5 BITS)
30
24
26
CLK IN
MV600
PPM DECODER
PPM
SL486
PPM AMP
22
20
IR 5BIT PPM ENCODED SIGNAL

Fig. 1b



16
18
MV500
PPM ENCODER
14
BC184L
ELECTRONIC SWITCH
10
BASE AROUND BRY82 20 SEC. PERIOD ASTABLE 1:200 M/S
12
MEAN BADGE CURRENT DRAIN = 70μA

Fig. 1a

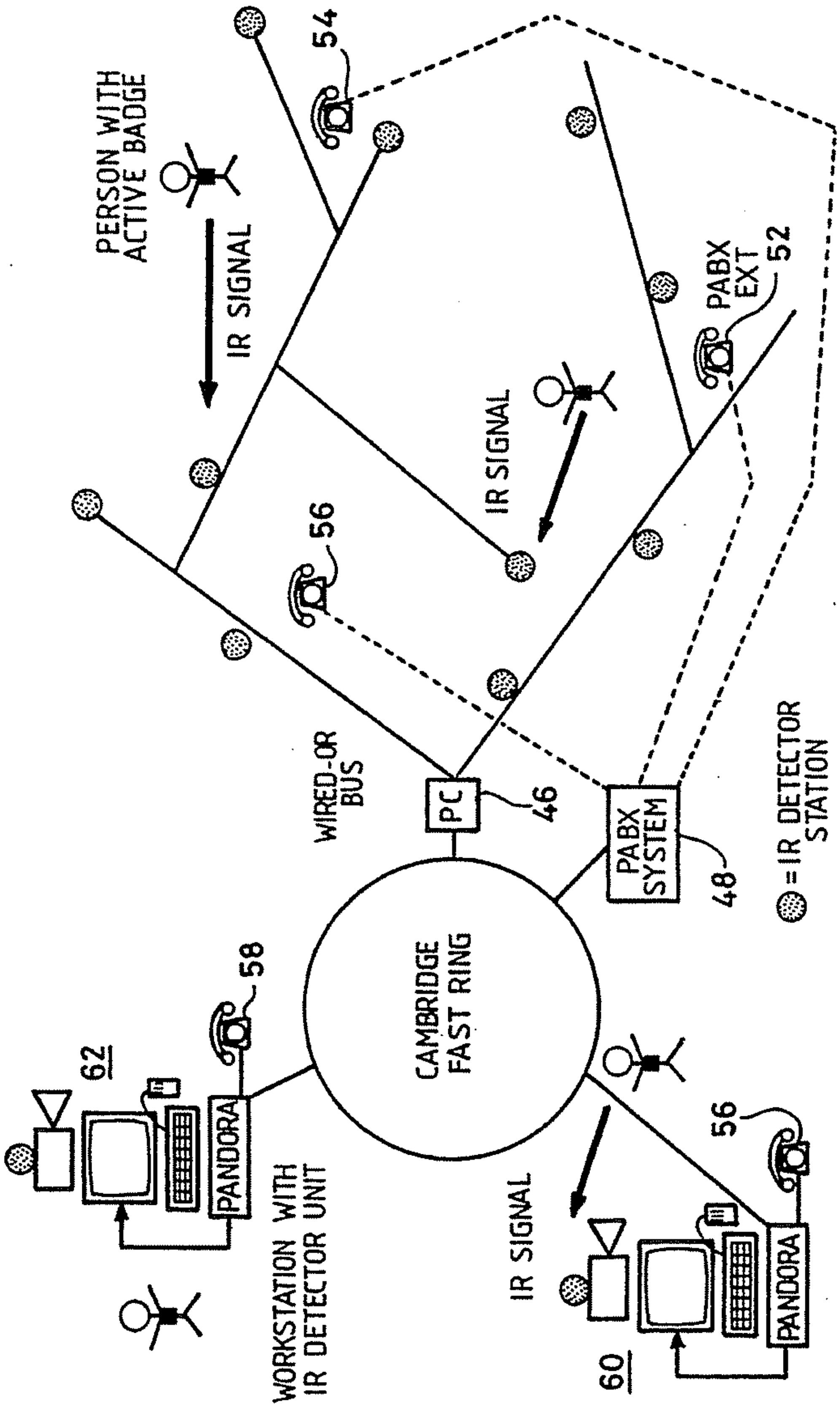

PERSON WITH ACTIVE BADGE
IR SIGNAL
54
PABX EXT
52
IR SIGNAL
56
WIRED-OR BUS
PC
46
PABX SYSTEM
48
= IR DETECTOR STATION
CAMBRIDGE FAST RING
58
62
PANDORA
WORKSTATION WITH IR DETECTOR UNIT
IR SIGNAL
56
PANDORA
60

Fig. 2

CARRIER LOCATING SYSTEM

RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 590, 012, filed Sep. 28, 1990, and now abandoned.

FIELD OF THE INVENTION

This invention concerns a system for locating the whereabouts of mobile carriers (which may be vehicles or people or animals or any movable items) within a predetermined environment.

BACKGROUND OF THE INVENTION

Paging systems are known whereby a centrally located operator can call up a person by name over a tannoy system.

Radio paging systems are also known whereby in a similar manner, but with greater secrecy, each one of a group of people carrying individual radio receivers can be called up using a radio transmitter to transmit an appropriate call up signal to cause the appropriate one of the radio receivers to emit a signal (either audible or visual or both) to thereby alert the carrier to make contact with the central operator.

Both systems rely on a telephone system within the environment within which the called up people are located to enable the paged person to make contact with the central operator.

Neither system however enables the operator to determine in advance whether any particular carrier is actually within the environment and where, in the environment, the carrier is actually located at any particular time. In each case the operator only becomes aware of whether the carrier is within the environment let alone where the carrier is located, after the carrier has made contact with the operator by establishing a telephone link using a locally situated telephone receiver.

U.S. Pat. No. 4,601,064 to Shipley describes a communication system for locating or tracking persons or objects to automatically establish two-way conversation with the person located via an associated intercom or telephone system. The locating system requires each person or object to be located, to carry an infra-red pulse transmitter which operates continuously automatically and repetitively and generates a unique pulse train so that each carrier can be identified by decoding its pulse train. In different regions are located infra-red receiver units which are set to continuously receive transmitter pulse signals. Each receiver includes a memory capable of storing the identifying data (derived from a received pulse transmitter) of one carrier, and to avoid confusion the identifying data stored in the receiver is erased either as a result of the receiver being polled or by the reception of a new pulse train, whether from the same or a different transmitter.

Such a system is economically as regards memory capacity for each receiver but clearly data can be lost if the polling rate is not high enough.

In order to permit a high polling rate Shipley proposes a 20 wire multiple cable to enable a parallel data bus system to be used which enables a very high polling rate, so that each receiver should be interrogated at least as frequently as randomly transmitted pulse transmissions will be received from carriers in the region.

In order to reduce the need for such high polling rates, Shipley proposes that if lower polling rates are

used, certain identifying pulse train data signals may be lost due to being replaced by a later transmitted pulse train from another transmitter. On a statistical basis, if one of the identifying data signals is not seen during the end of one interval by a first polling, statistically it may be resident in the receiver memory during a subsequent polling and Shipley therefore proposes to accumulate values over a number of polls in order to identify a number of transmitters in a given region, but only after a number of pollings have occurred. This would certainly enable a number of different transmitter units within one region to be separately seen by the receiver unit associate therewith and recorded by the central processor but not as a result of a single polling, only after a number of pollings have occurred.

In the experience of the inventors of the present invention, however, systems such as Shipley are high in cost in view of the vast amount of copper cable which is required and such systems are also unreliable due to the large number of interconnections and the possibility of high resistance or open circuit connections occurring and the resulting loss of data. In addition, the electrical capacitance of such cabling is such that if the length of multiway cable is excessive, the bandwidth limitation can easily render the system incapable of operating at the polling rates required by the Shipley system so that essentially such a system can only be considered for a relatively small building.

The invention of the present application has no such problems, and obviates the inherent design disadvantages incorporated in the Shipley system, that is, the need for a parallel data bus, high polling rates and multiple polling.

It is therefore an object of the present invention to provide a system which does not require a parallel data bus nor high polling rates nor multiple pollings by which a central controller (which may be a person or programmed computer), can rapidly determine whether a particular carrier is located within a given environment and if so where the carrier is located within the environment, to thereby enable the controller to make contact with the carrier by using a standard internal telephone system to cause a telephone near to where the carrier is locate to ring, and route an incoming telephone call directly to a telephone convenient to where the carrier is actually located at the time the call is received.

SUMMARY OF THE INVENTION

According to one aspect of the invention a system for locating the whereabouts in a predetermined environment of each of a plurality of carriers, comprises:

a) Transmitter means on the carriers for transmitting identifying signals, each transmitter producing a unique signal;

A plurality of receiver means located in each of a corresponding plurality of separate defined regions making up the predetermined environment and each adapted to receive any of the unique identifying signals should any of the transmitting means be within range, each receiver means including a FIFO buffer memory to which carrier identifying data is inserted whenever a transmission from a carrier is received, and

c) A controller adapted to interrogate each of the plurality of receiver means in turn to record the identifying data (obtained from the FIFO buffer memories as they are addressed), with regional data, thereby linking

the carrier identifying data with positional identifying data relating to the environment.

Preferably the transmitter means transmit identifying signals for short durations of time which are well spaced by larger intervals of time, and preferably a degree of randomness is introduced into the spacing period so as to reduce the risk of simultaneous transmissions.

In a system in which incoming telephone calls which contain a unique extension code are to be routed automatically by a programmed computer which is to use the extension code to identify the carrier to whom the call is to be routed, the computer operates so as to determine the current positional data linked to the carrier data associated with the extension code and thereby enable the region (and therefore a convenient telephone extension) to be identified, whereby the incoming call can be routed to that telephone extension.

In a system in which incoming telephone calls are intercepted by a human operator, display means may be provided such as a screen or mimic diagram or the like and input means is available to the operator to enter data which identifies the carrier to whom the call is to be routed, and a programmed computer operates in response to such input to display on the screen (or otherwise), information which may enable the operator to ascertain the region in which that carrier was last located or, may advise the operator of the appropriate telephone extension number to which to route the calls.

Conveniently the transmitter means includes an infrared source and driver therefor and the receiver means includes an infra-red sensitive transducer (such as an infra-red sensitive diode) and signal amplifier.

Preferably each transmitter means includes a PPM encoding device which drives a infra-red emitting diode, and switch means, and a pulse generator and timing circuit means are provided for determining the intervals during which the diode is to transmit coded information.

By arranging that each of a plurality of transmitters to be used by carriers within a given environment each transmits a uniquely coded signal for only a very short period of time which itself is relatively randomly determined, so each receiving means will in general only received a single carrier transmission at any instant in time and each carrier can be uniquely identified and its position determined as aforesaid.

If it is essential that two transmissions from carrier mounted transmitter units never occur simultaneously, a form of time division and synchronisation must be built into each carrier mounted transmitter to prevent any such occurrance. Thus in one form of such a transmitter, a crystal controlled timing device is incorporated which is set to produce trigger signals for releasing coded carrier data from the transmitter on a repetitive synchronous basis, which can be pre-set within a series of time slots so that each transmitter unit only transmits coded carrier data during one of said time slots within each repetitive period of time.

Alternatively receiver means may be incorporated within each transmitter means and a synchronous timing signal may be transmitted throughout the whole environment by transmitter means associating with each said receiver located within each region within the environment, so that all of the receivers are locked into synchronous operation and each receiver is pre-programmed to transmit coded data relating to the carrier in a strictly defined period of time following each synchronous signal, each of the periods of time being different for the different transmitters to thereby again eliminate the possibility of duplication of transmission within any given region.

The components making up each transmitting means may be miniaturised and packaged together with a miniature battery onto a badge or device which can be worn or carried externally by a person or mounted on a vehicle or other item or animal which is to monitored.

Such receiver means conveniently comprises a PPM decoder for generating digital data for storing in the FIFO memory and a controller and an address ROM into which address data is entered on installation, uniquely indicating in coded format the location of that receiving means relative to the overall environment.

Data in the FIFO memory of a receiving means may be read out by transmitting an address corresponding to that in the address ROM of the receiving means concerned, so causing the receiver controlled to interrogate the associate FIFO memory and to transmit the decoded carrier data stored therein, together with coded data indicating the identity (and therefore the location) of the receiving means.

A FIFO buffer memory is required in practice, to prevent data being lost if a number of carrier transmitter devices should transmit data in quick succession, an so that the interrogating loop can be interrupted for short periods without data loss.

The interrogation loop may be a 4-wire OR'd network operating at 4800 Baud.

The invention will now be described by way of example with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a* and **1***b* together show a block schematic diagram of a mobile carrier position locating system embodying one aspect of the present invention; and

FIG. **2** is a schematic diagram showing how a plurality of receivers may be connected to a central processor and via a data network inter alia to a PABX and other work stations in a work environment.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIGS. **1***a*, **1***b* the essential parts of a mobile "badge" transmitter are shown in FIG. **1***a* and likewise the essential parts of one of the zone receivers are shown in FIG. **1***b*, such as are employed in a badge position locating system incorporating the invention. In the overall system a receiver such as shown in FIG. **1***b* is located in each zone to be interrogated and is hard wired via a multi-path highway to a central processor for interconnecting telephones in a PABX system, such as shown in FIG. **2**.

As shown in FIG. **1***a* each transmitter **10** comprises a battery power supply (not shown) for powering a 20-second period astable multi-vibrator **12** for producing pulses having 1:200 mark to space ratio.

The multi-vibrator is based around a BRY62 device and provides control pulses for operating an electrical switch **14** based on a BC 184L device. Switch controls are device type MV500 arranged as a PPM encoder **16** for driving an infra-red transmitting element **18** such as an infra-red emitting diode.

Each receiver unit comprises an infra-red detector **20** which feeds the input to a PPM high gain signal amplifier **22** based on a device type SL486, the PPM output of which is supplied to a PPM decoder **24** based on the

device type MV600. the Latter provides a clock pulse signal along a path 26 to a 16×5 FIFO buffer store 28 based on device type MV6640410P, to which 5-bit data is supplied to the data input of the device via path 30.

FIFO buffer store 28 is also triggered by clock pulses from a central processor device 32, such as device type MC14489, and delivers the 5-bit data words to the data input terminal of the processor device 32. The processor also receives control signals denoting when the FIFO is FULL or EMPTY.

The processor 32 is powered from a 5 volt line 34 and is connected to the negative side of a supply such as a mains powered power supply unit (not shown).

A station address is set up by pre-set switches 36 and the processor 32 is programmed to transfer the data stored in the FIFO buffer 28 to a data bus 38 (forming part of a four-wire highway). The latter comprises a 5 volt line 40, a ground line 42 and a second data line 44.

Referring again to FIG. 2, the central processor is shown as a personal computer 46 programmed to deliver a sequence of station addresses along the data line 44. When a detector station processor 32 receives a station address signal corresponding to the address as set up by its associated switches 36, the data in its associated FIFO memory is transmitted via the processor 32 to data line 38 and thence to the central processor of computer 46.

The rate at which different station addresses are transmitted by the computer 46 is selected such that there is at least sufficient time for a completely filled FIFO memory to be read out between one receiver address and the next. Thus where the FIFO memory device is a 16×5 bit device the time between receivers addresses must be at least equal to the time for 80 bits of data to be transmitted from the receiver to the computer 46 together with the addressing data and any handshake protocols at the beginning and ending of each data transmission from a receiver to the computer.

The central processor PC46 is programmed to link the zone address signals with the badge identifying signals from each FIFO MEMORY, within a memory associated with the computer 46, so that badge signals are associated with particular zone identification signals and the PC can be interrogated in a conventional manner to indicate the zone within which any particular bade, or group of badges, is currently located.

In the general case, if up to N different carriers can be located in any one region of the overall environment at any one time, and each unique carrier identifier signal is made up of n bits of data, then the FIFO memory of each receiver must be capable of storing N×n bits of data. Likewise the controlling PC 46 must be capable of linking up to N different carrier identifiers with one regional identification data signal and the polling rate must not be greater than one receiver per T seconds, where T is the time in seconds for transmission of (N×n) bits of data plus the time required to address the receiver and receive location identifying data.

As shown in FIG. 2 the central processor PC46 can be arranged to set up ringing and speech paths via a PABX 48 to any one of a number of telephone extensions 50, 52, 54, 56 and 58. A ring bus such as Cambridge Fast Ring may be employed to link work stations such as 60 and 62 to the central processor 46 and the same ring may be employed to transmit signals to and from the telephone extensions 56 and 58, as well as data to and from the work stations 60 and 62, and the computer PC46–and if appropriate, via the PABX, to external telephone lines using modems.

In use the system allows incoming external calls for a particular person, routed via the PABX 48, to transmit a ringing signal to the telephone extension in the zone within which the identified person is located. This is achieved by allocating a unique identification number to each person to whom calls are to be so directed, and to issue to that person a badge having as its "call sign" the same number. An incoming call including that number (corresponding effectively to a telephone extension number) is decoded by the PC46, and the memory within the PC46 consulted for the same number. When found, the zone identification for that badge number is noted and a ringing tone is transmitted to a telephone extension within the identified zone. (Where there is only one telephone in each zone, the routing is relatively straightforward and can be completed (or not) depending on whether the telephone extension is busy or free. Where more than one telephone is located in each zone (as will normally be the case) the routing will be slightly more complicated but can be arranged using some form of hierachy, or simply random selection, of available extensions).

Altervatively the routing of the incoming call may be by a telephone operator who can interrogate the PC46 using the badge number of the required person, to call up the zone within which they can be found, before selecting the telephone extension to be rung, to enable the incoming call to be connected to a telephone in close proximity to the called person.

We claim:

1. A system for locating the whereabouts in a predetermined environment of each of a plurality of carriers, comprising:

a) transmitter means on the carriers for transmitting identifying signals, each transmitter means producing a unique signal which therefore identifies the carrier;

b) a plurality of receiver means respectively located in a corresponding plurality of separate defined regions making up the predetermined environment and each adapted to receive any of the unique identifying signals when any of the transmitting means are within range, each receiver means including a solid state FIFO buffer memory capable of sequentially storing carrier identifying data of a plurality of different carriers, and into which carrier identifying data is inserted whenever a transmission from a carrier is received; and

c) a controller adapted to interrogate each of the plurality of receiver means in turn, to address the FIFO buffer memory in each receiver and obtain and record the carrier identifying data therein in association with data defining the region within which the receiver is located, thereby linking the carrier identifying data with positional identifying data relating to the environment.

2. A system as claimed in claim 1, wherein each transmitter means transmits identifying signals for particular durations of time which are spaced by intervals of time, which are greater in duration than said particular duration.

3. A system as claimed in claim 2, wherein, within limits, randomness is introduced into the spacing intervals of time so as to reduce the risk of simultaneous transmissions.

4. A system as claimed in of claim 1, applied to a telephone system in which incoming telephone calls which contain a unique extension code are routed automatically by a programmed computer which uses the extension code to identify the carrier to whom a call is to be routed, wherein the computer also operates so as to determine the current positional data linked to the carrier data associated with the extension code and thereby enable the identification region, and therefore the identification of a convenient telephone extension, whereby the incoming call is routed to that telephone extension.

5. A system as claimed in claim 1, applied to a telephone system in which incoming telephone calls are intercepted by a human operator, including display means, operator input means for enabling the operator to enter data which identifies the carrier to whom a call is to be routed, and a programmed computer which operates in response to such input to display information which either enables the operator to ascertain the region in which that carrier was last located or advises the operator of the appropriate telephone extension number to which to route the call.

6. A system as claimed in claim 1, wherein each transmitter means includes an infra-red source and driver therefor and each receiver means includes an infra-red sensitive transducer and signal amplifier.

7. A system as claimed in claim 6, wherein each transmitter means includes a PPM encoding device which drives an infra-red emitting diode and switch means, and a pulse generator and timing circuit means are provided for determining the intervals during which the diode is to transmit coded information.

8. A system as claimed in claim 1, wherein, in each transmitter means, a crystal controlled timing device is incorporated which is set to produce trigger signals for releasing coded carrier data from the transmitter on a repetitive synchronous basis, which timing device can be pre-set within a series of time slots so that each transmitter means only transmits coded carrier data during a unique one of said time slots within each repetitive period of time.

9. A system as claimed in claim 1, wherein a control receiver is incorporated within each transmitter means and a synchronous timing signal is transmitted throughout the whole environment, so that all of the control

receivers are locked into synchronous operation, and each control receiver is pre-programmed to cause its associated transmitter means to transmit coded data relating to the carrier in a strictly defined period of time following each synchronous signal, the periods of time being different for the different transmitter means.

10. A system according to claim 1, wherein the components making up each transmitting means are miniaturised and packaged together with a miniature battery into a device which can be worn or otherwise carried externally by a person or vehicle or other item or animal which is to be monitored.

11. A system as claimed in claim 1, wherein each receiver means comprises a PPM decoder for generating digital data for storing in the FIFO memory and a controller and an address ROM into which address data is entered on installation, uniquely indicating in coded format the location of that receiving means relative to the overall environment.

12. A system as claimed in claim 11, wherein data in the FIFO memory of a receiving means is read out by transmitting an address corresponding to that in the address ROM of the receiving means concerned, so causing the receiver means controlled to interrogate the associated FIFO memory and to transmit the decoded carrier data stored therein, together with coded data indicating the identity, and therefore the location, of the receiving means.

13. A system as claimed in claim 12, wherein an interrogation loop associated with each FIFO memory is a 4-wire OR'd network operating at 4800 Baud.

14. A system as claimed in claim 1, in which the FIFO buffer is formed to store up to N (N greater than 1) carrier identifiers each of n bits, whereby each receiver is thereby able to receive and retain carrier identifiers of up to N carriers, and in which said controller is adapted to obtain and record up to N items of carrier identifying data therein in association with data unique to a region.

15. A system as claimed in claim 14, in which the controller transmits a new receiver address after a period of time at least equal to that required to transmit at least $(n \times n)$ bits of data from the FIFO memory in the receiver to the controller and receiver identifying data.

* * * * *

US005150310A

United States Patent [19]

Greenspun et al.

[11] Patent Number: 5,150,310

[45] Date of Patent: Sep. 22, 1992

[54] METHOD AND APPARATUS FOR POSITION DETECTION

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[73] Assignee: Consolve, Inc., Lexington, Mass.

[21] Appl. No.: 400,354

[22] Filed: Aug. 30, 1989

[51] Int. Cl.[5] G01S 3/02

[52] U.S. Cl. 364/516; 364/460; 364/452; 342/451

[58] Field of Search 364/516, 559, 569, 451, 364/443, 460, 461, 450; 342/47, 147, 118, 451; 340/977, 979

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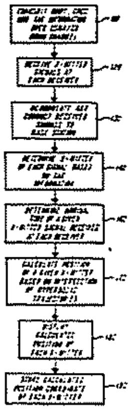
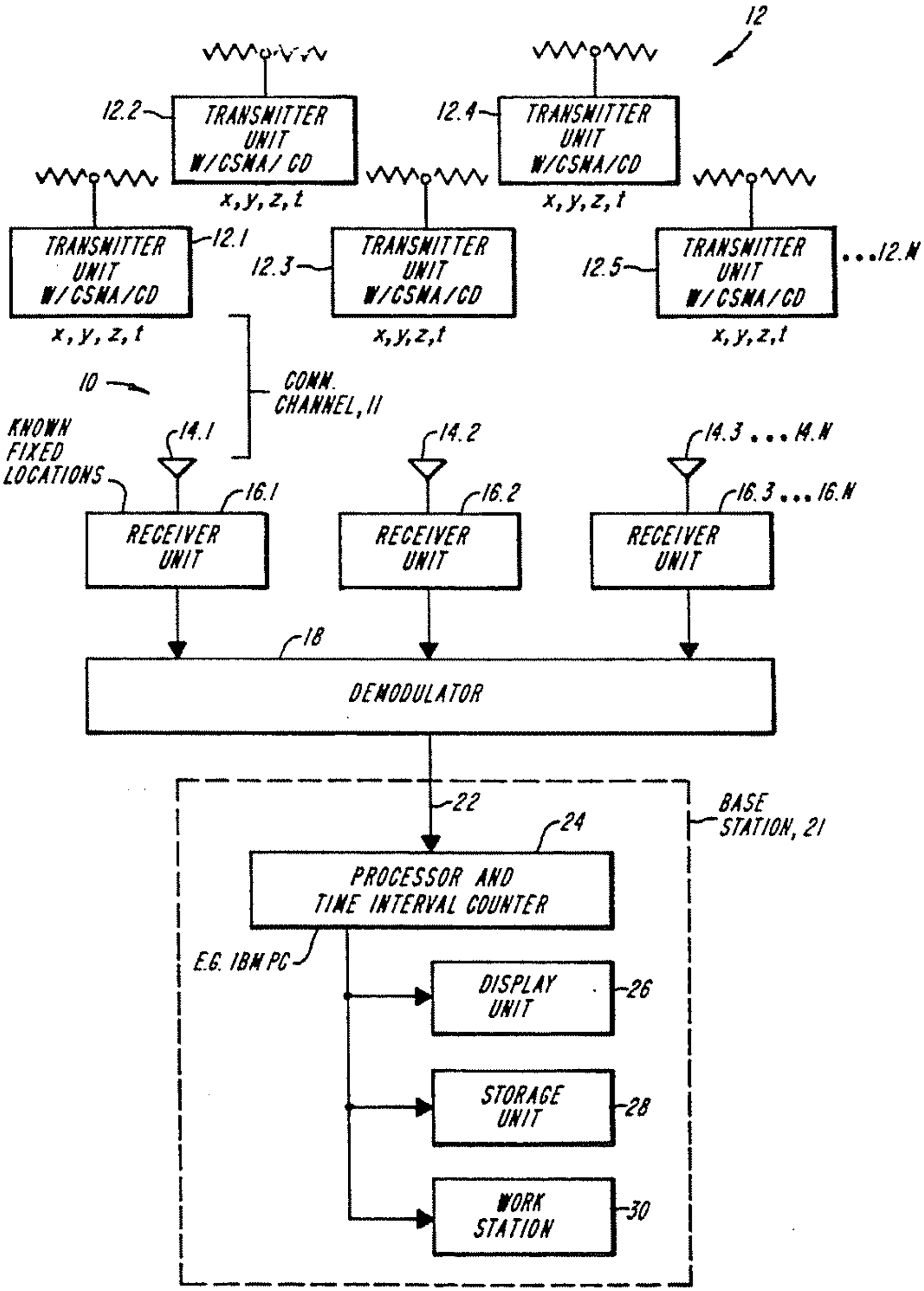
Primary Examiner—Thomas G. Black
Assistant Examiner—Ellis B. Ramirez
Attorney, Agent, or Firm—Lahive & Cockfield

[57] ABSTRACT

Position detection methods and apparatus include transmitters, coupled to each object to be tracked, for transmitting signals uniquely identifying each transmitter. Receivers disposed at known locations receive the transmitted signals and generate received signals representative of the transmitted signals. Arrival-time elements, responsive to a selected zero-crossing or other event in each received signal, determine the respective arrival time of each transmitted signal at each receiver. A processor calculates differences in arrival times of the transmitted signals at each receiver, and determines the spatial position of each object with respect to the known locations of the receivers.

33 Claims, 4 Drawing Sheets

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16.3 ... 16.N
RECEIVER UNIT
RECEIVER UNIT
RECEIVER UNIT
18
DEMODULATOR
22
24
BASE STATION, 21
PROCESSOR AND TIME INTERVAL COUNTER
E.G. IBM PC
DISPLAY UNIT
26
STORAGE UNIT
28
WORK STATION
30

FIG. 1A

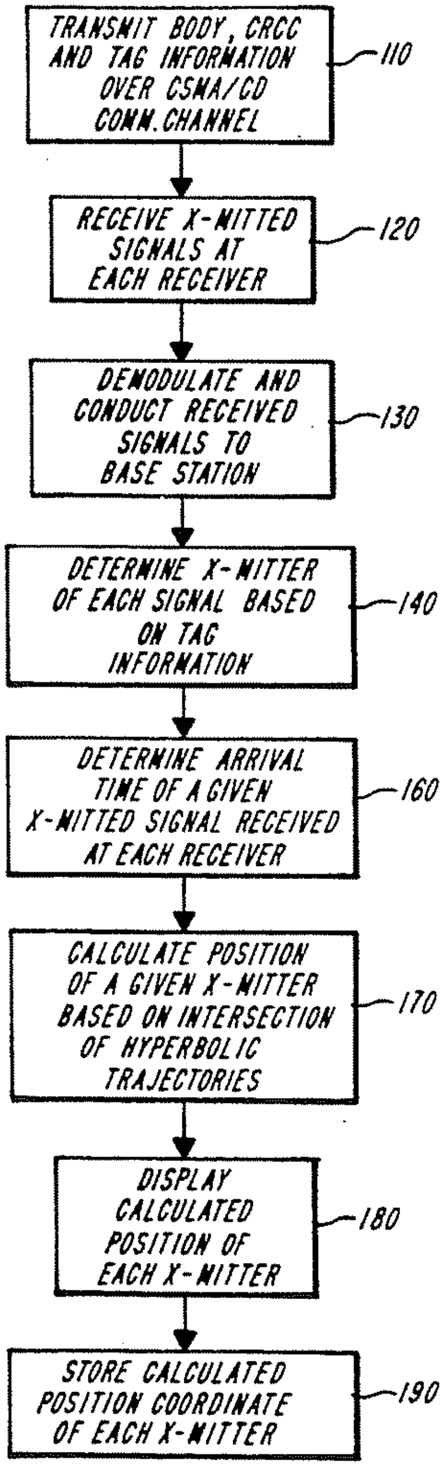
TRANSMIT BODY, CRCC AND TAG INFORMATION OVER CSMA/CD COMM. CHANNEL
110
RECEIVE X-MITTED SIGNALS AT EACH RECEIVER
120
DEMODULATE AND CONDUCT RECEIVED SIGNALS TO BASE STATION
130
DETERMINE X-MITTER OF EACH SIGNAL BASED ON TAG INFORMATION
140
DETERMINE ARRIVAL TIME OF A GIVEN X-MITTED SIGNAL RECEIVED AT EACH RECEIVER
160
CALCULATE POSITION OF A GIVEN X-MITTER BASED ON INTERSECTION OF HYPERBOLIC TRAJECTORIES
170
DISPLAY CALCULATED POSITION OF EACH X-MITTER
180
STORE CALCULATED POSITION COORDINATE OF EACH X-MITTER
190

FIG. 1B

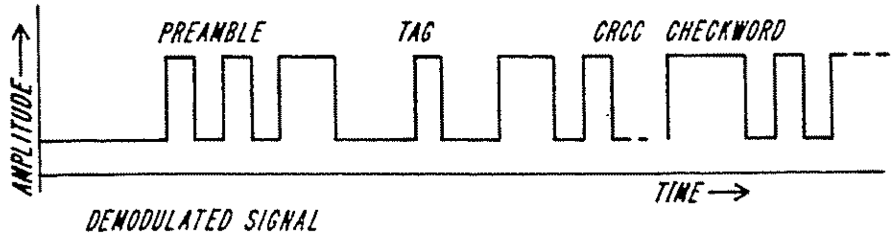

FIG. 2A

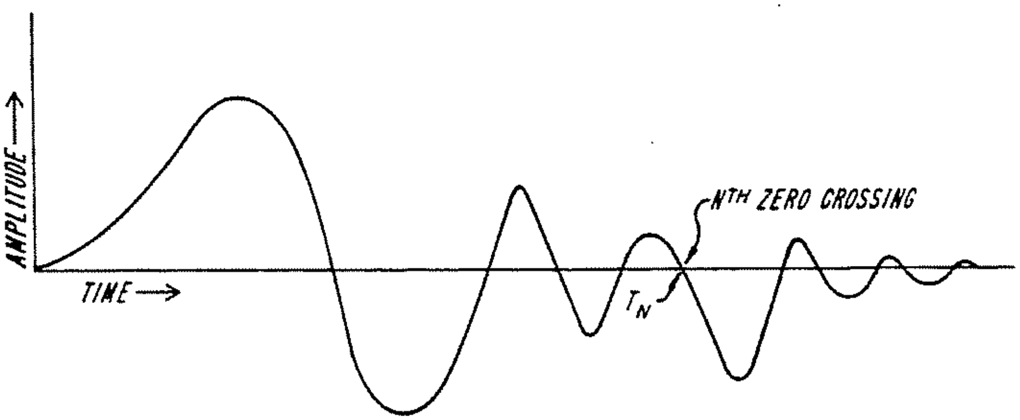

FIG. 2B

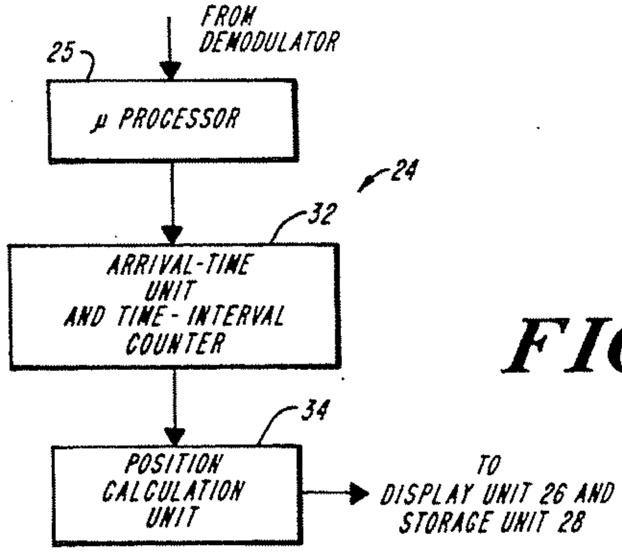

FIG. 3A

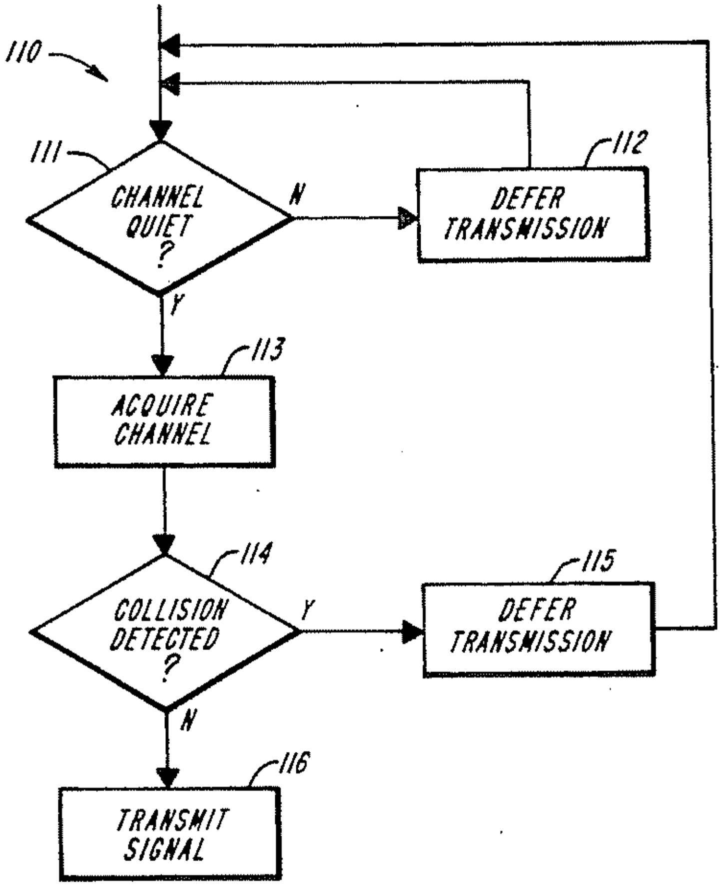
110
111
CHANNEL QUIET ?
N
Y
112
DEFER TRANSMISSION
113
ACQUIRE CHANNEL
114
COLLISION DETECTED ?
Y
N
115
DEFER TRANSMISSION
116
TRANSMIT SIGNAL

FIG. 3B

METHOD AND APPARATUS FOR POSITION DETECTION

BACKGROUND OF THE INVENTION

This invention relates generally to systems for position detection and ranging, and, more particularly, relates to apparatus and methods for precise determination of the position of multiple movable objects, utilizing transmission and detection of electromagnetic energy.

Position detection and tracking of movable objects is useful in a wide variety of applications, including construction site vehicle tracking, fleet vehicle dispatch and monitoring, courier monitoring, industrial robot control, tracking of animal migration, monitoring of human operatives or mechanical devices in remote areas, and battlefield command and control.

A number of systems have been proposed or constructed for monitoring the position of movable objects by dispatch personnel, or for advising vehicle operators of instantaneous position. Conventional LORAN systems, for example, carried by air- and seacraft, inform the pilot of vehicle position with respect to multiple transmitters situated at known, fixed locations. In these systems, measurement of distance between the vehicle and transmitters is implemented by comparison of phase between arriving signals. The following U.S. and foreign patents and patent applications disclose various position measurement or detection systems.

Cain et al.	4,756,617
Cain et al.	4,732,471
Win et al.	4,730,190
Reinaud	4,703,820
Petersen	4,676,634
Cain et al.	4,674,870
Ikeda et al.	4,674,054
Christy et al.	4,665,404
Van de Velde et al.	4,659,982
Izutani et al.	4,658,257
Sekine	4,644,358
Huck, Jr. et al.	4,630,685
Cain et al.	4,600,997
Miller et al.	4,537,502
von Pieverling	4,536,763
Ward	4,488,154
Buck et al.	4,453,825
Wind	4,433,335
Hammada et al.	4,413,904
Vachenauer et al.	4,319,243
Etsusaki et al.	4,273,196
Hill et al.	4,171,907
Brenner	4,140,060
Zindler	4,119,379
Endo	4,110,754
Roeder et al.	4,106,017
Roeder et al.	4,103,302
Martens	4,021,116
Halajian et al.	3,864,513
Cornsweet	3,864,030
Funk et al.	3,775,735
Hotston	3,757,330
Heflinger	3,743,418
Ross	3,652,161
Studebaker	3,588,249
Green	1,750,668
German	3,311,349
German	3,234,446
German	2,853,317
German	2,620,809
Great Britain	2,076,152
Soviet Union	742,844
East Germany	229,866

The Ikeda et al. patent discloses a radio system for automatic control and positioning of machinery. The system includes high frequency inductive radio cables located in pairs along the paths taken by the machines. The cables are connected to address detectors and transceivers in a centrally controlled system. Each machine is provided with a radio and antenna for receiving commands from the controller. The controller detects the location of each machine, as indicated by phase shift of the lines.

The Christy et al. patent discloses a positioning system including base stations having a clock, and a circuit synchronized with the clock for transmitting a spread-spectrum signal. A mobile station comprises a clock synchronized with the base station clock. A circuit receives the spread signal and compares the timing of the signal to the timing of the mobile station clock for producing a phase difference signal indicative of range from a base station.

Van de Velde et al. discloses a microwave system including microwave receiving antennas and at least one correlator. A radiating antenna emits microwave radiation from a source having predetermined characteristics. The transmitted microwave signal is received by antennas at different locations, and circuits are provided to measure the time elapsed between two zero crossings of the received signals.

Sekine discloses an orientation measurement apparatus including an antenna for receiving global positioning system (GPS) radio waves and devices for rotating the antenna. Circuitry is provided for detecting the orientation of GPS satellite by detecting phase differences of the received wave during a period of rotation of the antenna.

Huck, Jr. et al. discloses apparatus for controlling a bulldozer or other earthmoving equipment. The apparatus evaluates longitudinal angular velocity of a bulldozer to control the position/elevation of the bulldozer blade.

Miller et al. discloses a target ranging system including a carrier frequency transmitter and a generator for generating at least two modulating signals for modulating the carrier. A receiver is provided for receiving a reflected signal from the target and for producing a corresponding received electrical signal. A phase detection device detects phase differences between the modulating signals and each of the received signals, and a data processor utilizes the detected phase differences to calculate range.

Ward discloses a radar processor including circuitry for deriving signals from reflections of directively radiated groups of at least three radar pulses in which the interpulse periods in each group are equal.

Buck et al. discloses an electronic distance meter which measures distance to a moving target by comparing the phase of a signal propagated to the target with the phase of the reflected signal.

Wind discloses a transmitter locating apparatus including circuitry for receiving electromagnetic radiation from the transmitter. The radiation is demodulated individually from each of plural receivers. A digital computer Fourier transforms the demodulated radiation and provides signals representing the radiation as a function of frequency. An additional computing device establishes a signal representing the phase difference between the demodulated radiation from each of the signals. The apparatus correlates signal timing differ-

ences to a hyperbolic surface of rotation on which the transmitter is located.

Vachenauer et al. discloses a system for determining the position of vehicles by measuring reception time differences. An area is scanned by a narrow beam from an electronically steered phased array antenna driven by the interrogating transmitter of a secondary radar system. A receiving antenna, remote from the interrogator and its beam, is similarly scanned. The identifying response from a transponder in a vehicle is received, and the vehicle position is computed from the differences between the times of reception, utilizing a hyperbolic algorithm.

Etsusaki et al. discloses a system for automatically maintaining the blade of an earthmoving machine in a predetermined relationship to a reference beam. A beam receiver, mounted on a rotatable shaft attached to the blade, includes vertically arrayed beam receiving elements for generating a signal representative of beam height. In response to the detected signal, actuators coupled to the blade raise and lower the blade to vertically align the beam receiver with the beam.

Hill et al. discloses an electro-optical distance measuring device including circuits for generating a light signal that is amplitude modulated by three selectable frequencies. Optics focus the modulated light onto the target, and receive reflection of the light therefrom. Additional circuits convert the received light to electrical signals representative of the light, and compute the phase angles between these signals and the amplitude modulating signals. The distance to the target is calculated from these phase angles.

Brenner discloses an optical system wherein pulses of optical energy are intensity modulated by a radio frequency subcarrier and transmitted to a moving target. Reflected pulses from the target are received, and target velocity information is generated from the doppler frequency shift of the radio frequency subcarrier of the return pulses.

The Roeder '017 and '302 patents disclose velocity sensors using a transmitter on an aircraft to direct a radar beam at an object. A receiver mounted on the aircraft receives reflected pulses through an antenna which has forward and aft phase center locations. A computer system performs a time/amplitude comparison of the signals detected at the aft phase center location against the signal detected at the forward phase center location a selected interval earlier in time.

Martens discloses electro-optical distance measuring apparatus for measuring the distance between a moving object and a stationary object. The apparatus includes circuitry for generating a series of cyclic radiation fringe patterns, which vary in correspondence with movement of the object being observed.

Hotston discloses an interferometer for measuring the distance to a moveable object. The interferometer includes a waveguide for radiating energy toward the object and for receiving energy reflected from the object.

Ross discloses distance measuring apparatus in which distance is measured by detecting the travel time of an energy pulse, using a measuring signal which is short relative to the distance being measured.

Green discloses apparatus for measuring the position of moving objects, including elements for transmitting, between fixed and moving stations, electromagnetic signals whose phase is related to a frequency generated at the fixed station. A comparison is made between the phase of the signal generated at the fixed station and the phase of a signal which has been shifted in phase by transmission. The position of the moving object is calculated from the phase adjustment necessary to bring the compared frequency components into phase with each other.

The German 3,311,349 publication discloses a position measurement system in which an optical receiver mounted on a vehicle is interrogated using a laser source. The laser source emits two encoded laser beam "barriers" in which each individual beam has both fixed and angle dependent laser beam modulation frequencies. The receiver provides a reference frequency, which is phased to the fixed source frequency. The receiver includes circuitry for measuring the time of receipt and the polarization direction of both modulation frequencies. Speed, direction and distance are determined from phase differences, receive times, and angles.

German 2,620,809 discloses a system for automatic position monitoring and control of an earthmover blade. A computer, utilizing information from angle transducers located on the earthmoving machine, compares the actual angles of elements of the blade to predetermined values required to create an embankment having a selected slope. In response, actuators regulate the motion and position of the blade to provide the selected embankment slope.

East German 229,866 discloses apparatus in which a hyperbolic position calculation is executed. The arrangement includes a command center, at least three measurement stations, and a mobile transmitter which is to be located. Transit time difference is measured by phase comparison and processed to enable a determination of mobile transmitter location.

Conventional systems typified by the disclosures of these publications, however, typically fail to provide rapid, precise, inexpensive measurement of the position of multiple movable objects in three spatial dimensions. Certain conventional position detection systems are hampered by data communications channels unable to provide high-speed multiple signal processing for precise, real-time ranging and position detection of multiple objects. Additionally, many conventional position detection and ranging systems require that each movable object be fitted with a relatively complex and expensive transceiver.

It is thus an object of the invention to provide position detection methods and apparatus which enable rapid, precise determination of object position in three spatial dimensions.

A further object of the invention is to provide position detection methods and apparatus which are relatively simple and economical to implement, wherein the bulk of electronic complexity and cost is allocated to a single base station, and wherein multiple target transceivers can be deployed at optimally low cost.

Another object of the invention is to provide such methods and apparatus which can utilize existing communications channels and apparatus.

Other general and specific objects of the invention will in part be obvious and will in part appear hereinafter.

SUMMARY OF THE INVENTION

The foregoing objects are attained by the invention, which provides methods and apparatus for precisely determining, in real-time, the spatial position of at least

one object, such as a vehicle. One aspect of the invention can include transmitters mounted on the targets, a set of receivers having known locations, and a central processor coupled to the receivers via a communications channel. Each transmitter periodically transmits a burst of pulsed energy. The receivers receive the pulsed energy bursts from each transmitter, convert them into pulsed electronic signals representative of the energy bursts, and provide the electronic signals to the central processor. The central processor evaluates a selected distance-independent event—such as a threshold crossing—in each electronic signal to establish the arrival time of the energy bursts at each receiver, and compares the arrival times of the energy bursts at each receiver to calculate the position of a corresponding transmitter.

In another aspect of the invention, the system is adapted for determining the position and attitude of multiple vehicles or personnel on a construction site. The central processor can be a microcomputer, and the pulsed energy bursts can include pulses that uniquely identify the transmitter, and pulses for error detection. The system can further include storage and display elements in communication with the central processor, for displaying and storing a representation of the site and the relative positions of vehicles and personnel.

In a further aspect of the invention, at least a first transmitter coupled to each object to be tracked transmits a first modulated electromagnetic radiation signal representative of a first digital bitstream. This first digital bitstream incorporates a set of selected tag bits uniquely identifying the first transmitter.

The invention further includes a plurality of receivers disposed at known locations, for receiving the first electromagnetic radiation signal and for generating digital received bitstream signals representative of the first digital bitstream. A position calculation module, coupled to the receiving elements, processes the received bitstream signals to calculate the spatial position of each tracked object with respect to the selected known locations of the receivers.

The position calculation module can include arrival-time elements, responsive to a selected event in each received bitstream signal, for determining a unique arrival time value for each received bitstream signal. These arrival-time values are representative of respective times at which the first electromagnetic radiation signal is received at respective receivers. The selected event in the received bitstream signal can include any of a selected threshold crossing or a selected signal value.

The position calculation elements also include a central processor, responsive to the arrival-time values, for calculating differences in arrival times of the first electromagnetic radiation signal at respective receivers, to determine the spatial position of each object with respect to the known locations of the receivers.

A further aspect of the invention includes signal demodulation elements, coupled to the receiving elements, for demodulating the received signals. These elements provide amplitude, frequency, phase, or baseband demodulation, depending upon the modulation of the signal emitted by the transmitters.

The invention also provides for controlling transmission of signals from each transmitter, by sensing transmission of signals from each transmitter, generating a collision detection signal in response to substantially simultaneous transmission of signals, and selectively enabling or deferring transmission in response to the collision detection signal. Transmission of signals can be deferred for a selected time period, or until the communications channel is quiet.

Error correction codes can be embedded in the transmitted signals, to be processed by error detection elements in the central processor, to enable detection of errors in the electrical receive signal.

The invention will next be described in connection with certain illustrated embodiments; however, it should be clear to those skilled in the art that various modifications, additions and subtractions can be made without departing from the spirit or scope of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description and the accompanying drawings, in which:

FIG. 1A is a block diagram depicting position detection apparatus constructed in accordance with the invention;

FIG. 1B is a flowchart illustrating the steps of a method according to the invention, implemented by the apparatus of FIG. 1A;

FIG. 2A depicts a demodulated, decoded signal generated by the system of FIG. 1A;

FIG. 2B depicts a modulated signal generated by the system of FIG. 1A;

FIG. 3A is a block diagram depicting components of the processor unit of FIG. 1A; and

FIG. 3B is a flowchart depicting steps implemented by the transmitters utilized in accordance with the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1A is a block diagram depicting a position detection system **10** constructed in accordance with the invention, for accurately determining the position of multiple movable objects, such as vehicles, personnel, or animals. The invention determines the position of each object by precisely measuring the arrival time, at receivers whose locations are fixed and known, of energy pulses emitted by transmitters affixed to the objects. The energy pulses can include radio, microwave, or light components, and can have selected identification or "tag" values, emitted from transmitters mounted in known locations on the objects to be tracked. The invention can utilize trigger circuits which generate a TTL-level pulse when a transmitted energy pulse is detected. As described below, a single, high-precision time-interval counter and microprocessor of conventional design and construction can be employed to determine, in real-time, the location of each of the multiple objects.

Referring to FIG. 1A, the system **10** can include transmitters **12.1**, **12.2**, . . . , **12.M** which can be affixed to each movable object. Each transmitter emits an energy pulse, which can include radio, light, or microwave energy components. The energy pulses can be transmitted over a communications channel **11**, in a manner discussed in greater detail hereinafter, and received by receivers **16.1**, **16.2**, . . . , **16.N** having corresponding antennas **14.1**, **14.2**, . . . , **14.N**, respectively. The received signals are conducted via a bus or communications channel **22** from the receivers **16** to a base station **21**. The base station **21** can include a demodulator unit **18** for demodulating the received signals, a processor and time interval counter module **24**, dis-

cussed in greater detail below, and conventional display unit **26**, storage unit **28**, and workstation **30** coupled to module **24**. While FIG. **1A** depicts the demodulator **18** as a discrete component contained in base station **21**, signal demodulation can alternatively be provided by multiple demodulator units, each corresponding to, and incorporated into, a respective receiver module. The demodulator unit **18** can incorporate circuitry of known design for providing selected demodulation of the received signals.

Referring to FIG. 1A and FIG. 1B (which presents a flowchart of a position detection method executed by the apparatus of FIG. 1A in accordance with the invention) each transmitter **12** can transmit a signal "burst" which is processed by the system **10** to obtain an accurate determination of the position of each transmitter **12**. This transmission is indicated in step **110** of FIG. 1B. The burst can include radio, light, or microwave energy components, can be digital or analog in form, and can be modulated in amplitude, frequency, phase, or baseband modes. The term "demodulation" is therefore defined herein to include amplitude, frequency, phase and baseband demodulation.

The invention can be practiced in connection with a variety of digital implementations, utilizing a number of different methods to transport a digital bitstream between the transmitters and receivers. For example, an RF baseband can be transmitted, with a selected portion being modulated by AM, FM phase, or as a spread spectrum transmission. Alternatively, an optical energy baseband can be generated, modulated in accordance with known optical signal processing techniques.

Moreover, as indicated in step **110** of FIG. 1B, the communications channel **11** between the transmitters **12** and the receivers **16** (FIG. 1A) is preferably managed by a distributed control protocol referred to as "carrier sense multiple access with collision detection" (CSMA/CD). The communications channel **11** can be implemented in connection with communications channel control elements analogous to those utilized in conventional communications networks utilizing the Ethernet protocol. The Ethernet is described in Shoch et al., *Evolution of the Ethernet Local Computer Network*, 1982, IEEE, incorporated herein by reference. The CSMA/CD protocol, and the function of communications channel control elements and transmitters **12** in conjunction with this protocol, are discussed in greater detail hereinafter.

The signal transmitted by the transmitters **12** and received by receivers **16** can include several components, as depicted in FIG. 2A. One component is a "tag" portion that uniquely identifies the transmitter. Each signal can begin with a known pattern of bits forming the preamble. This component can be used by the receiver to establish bit synchronization and then to locate the first bit of the packet. The preamble is inserted by the transmitter and can be stripped off by the controller at the base station.

Each signal can also include a cyclic redundancy checksum (CRCC) error checking word which, in accordance with conventional signal processing practice, can be utilized by the base station **21** to determine whether the transmitted signal was corrupted by interference or other communications problems. The CRCC checkword can include, for example, a sixteen-bit data word representative of the coefficients of a polynomial. Using this data word, the processor and time interval counter module **24**, contained in base station **21**, can perform error checking in a known manner, by shifting the received bits through a CRCC register to provide division by a selected quantity, and testing whether the register contents are equal to zero.

Again referring to FIGS. 1A and 1B, following transmission of signals over the CSMA/CD communications channel **11** (FIG. 1A) the receivers **16** receive the transmitted signals through respective antennas **14** (step **120** of FIG. 1B), and the received signals are conducted via bus or communications channel **22** (step **130** of FIG. 1B) to the base station **21**, for processing by demodulator **18** and processor unit and time interval counter module **24**. The processor and time interval counter module **24** can include, for example, a conventional microcomputer, such as an IBM PC. Those skilled in the art will recognize that the processor unit can alternatively be implemented in connection with any conventional digital or analog computer, microprocessor, computer, or computational circuit, designed, constructed, and programmed in accordance with known engineering principles. A preferred processor can include a reduced instruction set (RISC) device augmented by floating point calculation capabilities. Base station **21** can also include a transmitter, for communication back to mobile units, as well as a receiver. The structure and operation of these signal generating and processing components are addressed in greater detail hereinafter.

Referring again to FIGS. 1A and 1B, following receipt of emitted signals, the base station **21**, including the processor and time interval counter module **24**, determines which transmitter among a plurality of transmitters emitted a given received signal (step **140** of FIG. 1B). This determination is executed by processor and time interval counter module **24**, by evaluating the tag information contained in each signal.

Processor and time interval counter module **24** then assigns an arrival time value or an arrival time difference value to each signal (step **160** of FIG. 1B). The arrival time values or arrival time difference values, respectively, are representative of either the absolute time when each signal was received at each receiver, or the differences in arrival time among various signals. Each arrival time or arrival time difference value is assigned by the processor, in cooperation with the multiple receivers. In particular, arrival is signaled when the processor and time interval counter module **24** detects the occurrence of a selected event in the received signal. The selected event is preferably distance invariant, and can be, for example, a selected threshold crossing in an analog received signal. This is depicted in FIG. 2B, in which the Nth zero crossing, occurring at time Tn, is selected as the triggering event. Alternatively, if the received signal is digital, a selected top-of-bit value can be selected as the triggering event.

Moreover, steps **140** and step **160** of FIG. 1B can be reversed, so that arrival time or arrival time difference information is determined prior to identification of the transmitter associated with each received signal.

The system is configured so that each receiver **16** is at a known, fixed location, and there is a known propagation time between the receivers **16** and the base station **21**, including processor and and time interval counter module **24**. Accordingly, the arrival time or arrival time difference value of each received, demodulated signal at the processor can be utilized to calculate the position of each transmitter. In particular, the X, Y, Z coordinates of each transmitter, and the identity of each transmitter, are determined by the processor and time interval

counter module **24** incorporated within the base station **21**. The position of each transmitter can then be calculated (step **170** of FIG. **1B**) by known techniques, including computing a set of hyperbolic loci from arrival time differences, and calculating the intersection of the set of loci. As depicted in FIG. 3A, the processor and time interval counter module **24** can incorporate a conventional microprocessor **25**, an arrival time unit and time interval counter **32**, and a position calculation unit **34** to assign arrival times and calculate transmitter coordinates. The position calculation unit **34** can utilize conventional computational circuitry to solve for the intersection of hyperbolic curves, using known techniques such as Newton's method, to determine transmitter position. This hyperbolic position calculation is utilized because an arrival time difference between two receivers corresponds to the loci of possible positions along a hyperbolic curve. The processor and time interval counter module **24** can therefore evaluate arrival time differences to solve four equations for four unknowns —i.e., X, Y, Z, and T, where X, Y, Z are the coordinates of the transmitter, and T is the time of transmission. The system can therefore provide multi-axis (X,Y,Z) position detection. While position calculation unit **34** is depicted as a discrete component in FIG. 3A, its function can alternatively be implemented in microprocessor **25**, as discussed hereinafter. Those skilled in the art will appreciate that precision of position calculation is enhanced if the start of the time interval is triggered by the processor and time interval counter module **24** upon detection of an edge in the received signal, rather than a digital HIGH or LOW value. Thus, the triggering event could be the rising edge of the Nth bit following a recognized preamble, at which time the processor and time interval counter module **24** activates an accurate time interval counter contained in module **32** of FIG. 3A. This embodiment has measured differences in arrival time to within 25 picoseconds—i.e., within one-fortieth of a foot at the speed of light.

In applications where precision is less critical, the start of the time interval can be signalled by the Nth digital HIGH or top-of-bit, at which time the time interval counter in module **24** is activated. This method is less precise, but can suffice if the bitstream rate is very high. Alternatively, the processor **25** in module **24** can maintain a fast-running clock and digitally record arrival time at each receiver. Thus, where only moderate precision is required, the entire time interval measurement process can be implemented in software, if practiced in connection with a sufficiently powerful processor having a high clock speed. In such an embodiment, the preamble or Nth bit of the received signal would be time-stamped for measurement of arrival time differences.

In a preferred embodiment of the invention, a two-dimensional plan view or three-dimensional representation of the transmitter locations can be displayed—using known computer graphics techniques—at the base station (step **180** of FIG. **1B**) and stored (step **190** of FIG. **1B**) in the storage unit **28** of FIG. **1A**. Display output can be provided at the display unit **26** or workstation **30**. The transmitter locations can be superimposed on a map of the site or area of operations. Alternatively, the transmitter locations can be displayed and updated dynamically in three dimensions by remote computers, which can be linked to the base station by modem or other conventional communications devices.

In one embodiment of the invention, the transmitters **12** illustrated in FIG. 1A can include, for example, a simple frequency-modulated transmitter module. The transmitter module need not have a highly stable local oscillator. In one embodiment of the invention, each receiver demodulates a received signal into a TTL-level signal and repeats it over an optical or hard-wired communications channel to the base station **21**. The processor in module **24** of base station **21** can utilize a time-interval counter, such as the Stanford Research Systems SR620, to measure the difference in arrival time between the leading edges or other selected feature of the signals from pairs of receivers.

The transmitted signal can be Manchester-coded, a protocol in which each bit cell has two parts: the first half of the cell is the complement of the bit value and the second half is the bit value. Thus, there is always a transition in the middle of every bit cell, and this is used by the receiver to extract the clock and data values. If the transmitted signal is Manchester-coded, the processor **24** can utilize additional bits in the Manchester-coded signal to determine the identity of the transmitter, and utilize the final CRCC bits to determine whether the signal was corrupted by interference. The exemplary demodulated waveform shown in FIG. 2A corresponds to a Manchester-decoded transmitted signal—i.e., a signal from which the Manchester code has been removed—including identifying bits and CRCC bits.

As discussed above, the invention preferably utilizes a shared communications channel **11** by which the output of transmitters **12** is transmitted to receivers **16**. One configuration of a such a channel is described in Shoch et al., *Evolution of the Ethernet Local Computer Network*, 1982, IEEE, incorporated herein by reference. In one practice of the invention, the communications channel **11** is a shared RF transmission medium. The transmission medium can alternatively include other broadcast media, such as coaxial or optical cable.

The shared communications channel, as discussed above in connection with FIG. **1A**, is preferably managed by a distributed control protocol referred to as "carrier sense multiple access with collision detection" (CSMA/CD). The CSMA/CD protocol eliminates the requirement for a central controller managing access to the channel, and utilizes no pre-allocation of time slots or frequency bands. A transmitter unit **12** wishing to transmit to the base station **21** contends for the common shared communications channel **11** until it acquires the channel. When the channel is acquired, the unit employs it to transmit signals. This process (corresponding to step **110** of FIG. **1B**) is schematically illustrated in FIG. 3B.

To acquire the channel, each unit confirms whether the channel is in use—i.e., "carrier present"—by employing "carrier sense" (step **111** of FIG. **3B**). The presence of a signal is indicated by the presence of carrier, or transitions in received values. If the channel is in use, the unit defers transmission of signals (step **112**) until the channel is quiet. When quiet is detected, the unit immediately begins to transmit (step **113**). This is illustrated in the flowchart of FIG. 3B. During transmission, the sending unit monitors for a collision (step **114**)—i.e., other sending units attempting to use the channel at the same time.

In a correctly functioning system, collisions occur only within a brief time interval following the start of transmission, because after this interval, all stations will

detect carrier and defer transmission. This time interval is called the "collision window" or the "collision interval", and is a function of maximum propagation delay within the channel, or from one transmitter to another. If no collisions are detected (step **114**) during this time, a transmitter has acquired the channel and continues transmission of the packet (step **116**). If a sending unit detects collision (step **114**), the transmission of the remainder of the signal can be aborted (step **115**). To ensure that all parties to the collision have properly detected the collision, any sending unit which detects a collision can invoke a collision consensus enforcement procedure which briefly jams the channel. Each transmitter involved in the collision can then schedule its request for location for retransmission at some later time.

To minimize repeated collisions, each station involved in a collision can attempt to retransmit at a different time by scheduling the retransmission to take place after a random delay period. In order to achieve channel stability under overload conditions, a controlled retransmission strategy can be employed, in which the mean of the random retransmission delay is increased as a function of the channel load.

The CSMA/CD access procedure can be practiced in connection with any broadcast multi-access channel, including radio, twisted pair, coaxial cable, diffuse infrared, or fiber optic components. In one practice of the invention, collision detection can be implemented in conjunction with the processor and time interval counter module **24**, by executing a collision detection algorithm. In particular, the processor of module **24** can utilize a simple CRCC checksum to determine whether a signal collision has occurred, aborting signal processing if a collision is detected. The processor of module **24** can continuously monitor receiver output to detect the presence of transmitted signals. Monitoring can be implemented by known techniques such as polling loops or interrupt processing. The processor can generate a table of times at which signals are received, record the occurrence of communications channel collisions, and, where required, incorporate supplemental data into the bitstream, in addition to X, Y, Z, and T—where X, Y, Z are the coordinates of a given transmitter, and T is the time of transmission of a burst.

Those skilled in the art will appreciate that many conventional direction finding and position detecting systems do not employ time-interval measurement for high-precision position determination, because highly accurate time-interval measurement has only recently become available. The invention exploits the availability of accurate time interval measurement to provide a position detection system utilizing measurement of arrival time differences of an energy pulse at receivers placed at known locations. Moreover, the invention advantageously reduces the number of precision analog components required for position detection. The illustrated system can be constructed almost entirely from inexpensive digital components. Only one element—i.e., the time-interval counter incorporated in arrival-time module **32**, need contain high-precision analog components. This time-interval counter can consist of a commercially-available time-interval counter. Such counters, having sufficient accuracy and appropriate data interface ports for practicing the invention, can be obtained at moderate cost. As discussed above, a suitable time interval counter is manufactured by Stanford Research Systems of Sunnyvale, Calif.

The invention can be adapted to high-precision location of fleet vehicles and construction machinery at relatively short distances, or to position detection of aircraft, ships and other civilian and military objects over longer distances. In particular, the system is useful in air traffic control, harbor management, slope monitoring, mining, dam and waterways management, and can substantially reduce the cost of automated position monitoring systems.

Those skilled in the art will appreciate that methods and apparatus in accordance with the invention provide a number of advantages over the prior art. For example, only one component, the time-interval counter, need be constructed to high-precision tolerances. Accordingly, the cost and complexity of the system is reduced. Apparatus in accordance with the invention can be constructed from conventional cordless telephones and low-cost modems (e.g., 2400 baud). Users who already have a data link system can therefore obtain location information for the minimal additional cost associated with additional receivers. Such a system can provide position detection, data communication and collision detection, utilizing a shared communications channel to transport an information-carrying bitstream from the transmitters to each receiver.

Additionally, one-shot time interval measurements accurate to 25 picoseconds can be achieved, yielding distance measurement precision within one centimeter, depending on the shape of the received pulse, the design of the receivers and the location of the antennas. The positions of multiple sources can be determined in real-time.

It will thus be seen that the invention efficiently attains the objects set forth above, among those made apparent from the preceding description. In particular, the invention provides position detection methods and apparatus which enable rapid, precise determination of object position in three spatial dimensions, which are relatively simple and economical to implement, wherein the bulk of electronic complexity and cost is allocated to a single base station, and wherein the multiple movable object transceivers can be implemented at optimally low cost.

It will be understood that changes may be made in the above construction and in the foregoing sequences of operation without departing from the scope of the invention. Thus, for example, the invention may be practiced in connection with infra-red or microwave transmission and reception in place of the radio transmitters and receivers depicted in FIG. **1A**. An optical embodiment of the invention can utilize a rotating laser beam or Xenon strobe source associated with each transmitter. The Xenon strobe signal, for example, can consist of a plurality of flashes of the Xenon strobe. Additionally, a "hardwired" communications channel can be provided by utilizing pre-tensioned reels of fiber optic cable. The propagation time between receiver and processor is then related to the length of cable unreeled.

It is accordingly intended that all matter contained in the above description or shown in the accompanying drawings be interpreted as illustrative rather than in a limiting sense. It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention as described herein, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described the invention, what is claimed as new and secured by Letters Patent is:

1. A system for determining, in real-time, the spatial position of at least one object, the system comprising

transmitting means including at least one transmitter coupled to said at least one object for transmitting a modulated electromagnetic radiation signal, said transmitted signal being modulated with a data bitstream including transmitter identification data and having a time-variant waveform including a selected feature,

receiving means, including a plurality of receivers disposed at selected known locations, for receiving said transmitted signal and for generating an electrical receive signal representative of said transmitted signal,

demodulation means, coupled to said receiving means, for demodulating said electrical receive signal to generate a demodulated electrical signal, and

processing means, coupled to said demodulation means, for identifying said at least one transmitter and calculating, in response to said demodulated electrical signal, the spatial position of said at least one object with respect to said selected known positions of said receivers, said processing means including

arrival-time means for processing said demodulated electrical signal to generate arrival-time signals, said arrival-time signals being representative of respective arrival times at which said electromagnetic radiation is received at respective receivers,

said arrival-time means including means for generating arrival time signals in response to the selected feature in said time-variant waveform, and

calculation means, for processing said arrival-time signals associated with said at least one object and corresponding to respective receivers, to calculate the spatial position of said at least one object with respect to said selected positions of said receivers.

2. The system of claim 1 wherein said selected event includes any of a selected threshold crossing, or a selected edge in said waveform.

3. The system of claim 1 further including means for determining the spatial position of said at least one object in at least three orthogonal axes.

4. The system of claim 1 wherein said processing means further includes a microprocessor.

5. The system of claim 1 wherein said processing means further includes storage means for storing said position signals.

6. The system of claim 1 wherein said processing means further includes display means for displaying said position signals and arrival signals.

7. The system of claim 1 wherein said demodulation means provides any of amplitude, frequency, or phase demodulation of said electrical receive signal.

8. The system of claim 1 wherein said demodulation means provides baseband demodulation of said electrical receive signal.

9. The system of claim 1 wherein said transmitting means includes error correction code transmit means for incorporating an error correction code pulsetrain within said transmitted signal, each said error correction code pulsetrain being representative of a error correction code.

10. The system of claim 9 wherein said processing means further includes error detection means for recognizing each said error correction code pulsetrain within said demodulation signal to detect an error in said electrical receive signal.

11. The system of claim 1

wherein said transmitting means includes at least two transmitters, and

further comprising communication control means for controlling transmission of signals from each of said at least two transmitters.

12. The system of claim 11 wherein said communication control means includes

carrier sense means for sensing transmission of signals from each of said at least two transmitters, and

collision detection means, in communication with said carrier sense means, for generating a collision detection signal in response to substantially simultaneous transmission of signals by said at least two transmitters.

13. The system of claim 12 wherein said communication control means includes transmission control means, responsive to said collision detection signal, for selectively enabling and deferring transmission of signals from each of said at least two transmitters.

14. The system of claim 13 wherein said transmission control means includes means for deferring transmission of signals for a selected time period.

15. The system of claim 14 wherein said transmission control means further includes means for deferring transmission of signals from a given transmitter until at least one other of said at least two transmitters is inactive.

16. A method for determining, in real-time, the spatial position of at least one object, the method comprising

coupling at least a first transmitter to said at least one object,

transmitting with said at least first transmitter an electromagnetic radiation signal modulated with a data bitstream including transmitter identification data and having a time-variant waveform including a selected feature,

disposing a plurality of receivers at selected known locations,

receiving, using said receivers, said transmitted signal to generate an electrical receive signal representative of said transmitted signal,

demodulating said electrical receive signal to generate a demodulated electrical signal,

processing, utilizing a processor, said demodulated electrical signal, to identify said at least first transmitter and calculate the spatial position of said at least one object with respect to said selected known positions of said receivers,

said step of processing said demodulated electrical signal including the steps of

processing said demodulated electrical signal to generate arrival-time signals, said arrival-time signals being representative of respective arrival times at which said electromagnetic radiation is received at respective receivers,

said step of processing said demodulated electrical signal including the step of generating arrival time signals in response to the selected feature in said time-variant waveform, and

processing said arrival-time signals associated with said at least one object and corresponding to respective receivers, to calculate the spatial position of said at least one object with respect to said selected positions of said receivers.

17. The method of claim 16 wherein said selected event includes any of a selected threshold crossing, or a selected edge in said waveform.

18. The method of claim 16 further including the step of determining the spatial position of said at least one object in at least three orthogonal axes.

19. The method of claim 16 wherein said processing step further includes the step of utilizing a microprocessor.

20. The method of claim 16 wherein said processing step further includes the step of storing said position signals.

21. The method of claim 16 wherein said processing means further includes the step of displaying said position signals and arrival signals.

22. The method of claim 16 wherein said demodulation step includes the step of providing any of amplitude, frequency, or phase demodulation of said electrical receive signal.

23. The method of claim 16 wherein said demodulation step includes the step of providing baseband demodulation of said electrical receive signal.

24. The method of claim 16 wherein said transmitting step includes the step of incorporating an error correction code pulsetrain within said transmitted signal, each said error correction code pulsetrain being representative of a error correction code.

25. The method of claim 24 wherein said processing step further includes the step of recognizing each said error correction code pulsetrain within said demodulation signal to detect an error in said electrical receive signal.

26. The method of claim 16 further comprising the steps of

utilizing at least two transmitters for transmission of signals, and

selectively controlling transmission of signals from each of said at least two transmitters.

27. The method of claim 26 wherein said controlling step includes the steps of

sensing transmission of signals from each of said at least two transmitters, and

generating a collision detection signal in response to substantially simultaneous transmission of signals by said at least two transmitters.

28. The method of claim 27 wherein said controlling step further includes the step of selectively deferring transmission of signals from each of said at least two transmitters.

29. The method of claim 28 wherein said deferring step further includes the step of deferring transmission of signals for a selected time period.

30. The method of claim 29 wherein said deferring step further includes the step of deferring transmission of signals from a given transmitter until at least one other of said at least two transmitters is inactive.

31. A system for determining, in real-time, the spatial position of at least one object, the system comprising

strobe means, including at least one Xenon strobe element coupled to said at least one object, for generating at least one energy pulse,

receiving means, including a plurality of receivers disposed at selected known locations, for receiving said at least one energy pulse and for generating an electrical receive signal representative of said at least one energy pulse, and

processing means, coupled to said receiving means, for calculating, in response to said electrical receive signal, the spatial position of said at least one object with respect to said selected known positions of said receivers, said processing means including

arrival-time means for processing said electrical receive signal to generate arrival-time signals, said arrival-time signals being representative of respective arrival times at which said at least one energy pulse is received at respective receivers, and

calculation means, for processing said arrival-time signals associated with said at least one object and corresponding to respective receivers, to calculate the spatial position of said at least one object with respect to said selected positions of said receivers.

32. A system for determining, in real-time, the spatial position of at least one object, the system comprising

strobe means, including at least one rotating laser beam coupled to said at least one object, for generating at least one energy pulse of laser energy modulated with a data bitstream including strobe identification data,

receiving means, including a plurality of receivers disposed at selected known locations, for receiving said at least one energy pulse and for generating an electrical receive signal representative of said at least one energy pulse, and

processing means, coupled to said receiving means, for identifying the strobe means and calculating, in response to said electrical receive signal, the spatial position of said at least one object with respect to said selected known positions of said receivers, said processing means including

arrival-time means for processing said electrical receive signal to generate arrival-time signals, said arrival-time signals being representative of respective arrival times at which said at least one energy pulse is received at respective receivers, and

calculation means, for processing said arrival-time signals associated with said at least one object and corresponding to respective receivers, to calculate the spatial position of said at least one object with respect to said selected positions of said receivers.

33. A system for determining, in real-time, the spatial position of at least one object, the system comprising

strobe means, including at least one strobe element coupled to said at least one object, for generating at least one energy pulse,

the strobe means including radio transmitting means for transmitting at least one pulse of radio energy modulated with a data bitstream including strobe identification data and having a time-variant waveform,

receiving means, including a plurality of receivers disposed at selected known locations, for receiving said at least one energy pulse and for generating an electrical receive signal representative of said at least one energy pulse, and processing means, coupled to said receiving means, for identifying the strobe means and calculating, in response to said electrical receive signal, the spatial position of said at least one object with respect to said selected known positions of said receivers, said processing means including

arrival-time means for processing said electrical receive signals to generate arrival-time signals, said arrival-time signals being representative of respec-

tive arrival times at which said at least one energy pulse is received at respective receivers,

said arrival-time means including means for generating arrival-time signals in response to a selected event in said time-variant waveform, and

calculation means, for processing said arrival-time

signals associated with said at least one object and corresponding to respective receivers, to calculate the spatial position of said at least one object with respect to said selected positions of said receivers.

* * * * *

United States Patent [19]

Levinson et al.

[11] **Patent Number:** **4,611,198**

[45] **Date of Patent:** **Sep. 9, 1986**

[54] **SECURITY AND COMMUNICATION SYSTEM**

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[21] Appl. No.: **777,770**

[22] Filed: **Sep. 19, 1985**

[51] **Int. Cl.**[4] **G08B 1/08**

[52] **U.S. Cl.** **340/539**; 340/531; 340/536

[58] **Field of Search** 340/539, 531, 536, 345, 340/346; 455/1, 7, 9, 11, 12, 13

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Primary Examiner—Donnie L. Crosland

Attorney, Agent, or Firm—George H. Gerstman

[57] **ABSTRACT**

A security and communication system permits the location of signaling portable radio frequency transmitters which may be carried by individuals. If an individual signals with his portable frequency transmitter, a first signal is sent including a first individual identification code to identify the particular portable transmitter. The first signal is picked up by at least one of a plurality of radio frequency relays each positioned in a predetermined location. Such relays immediately transmit a second signal including the first identification code and also a second identification code to identify the individual relay that is transmitting the second signal. Thus the signal sent by the individual relay identifies the location and the specific identity of the particular portable radio frequency transmitter which is sending the signal.

19 Claims, 1 Drawing Figure

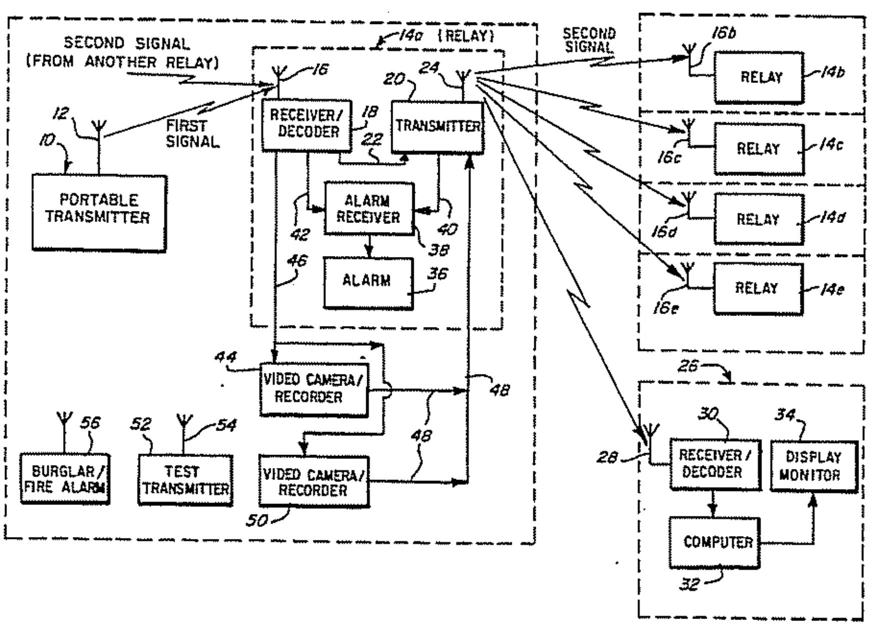
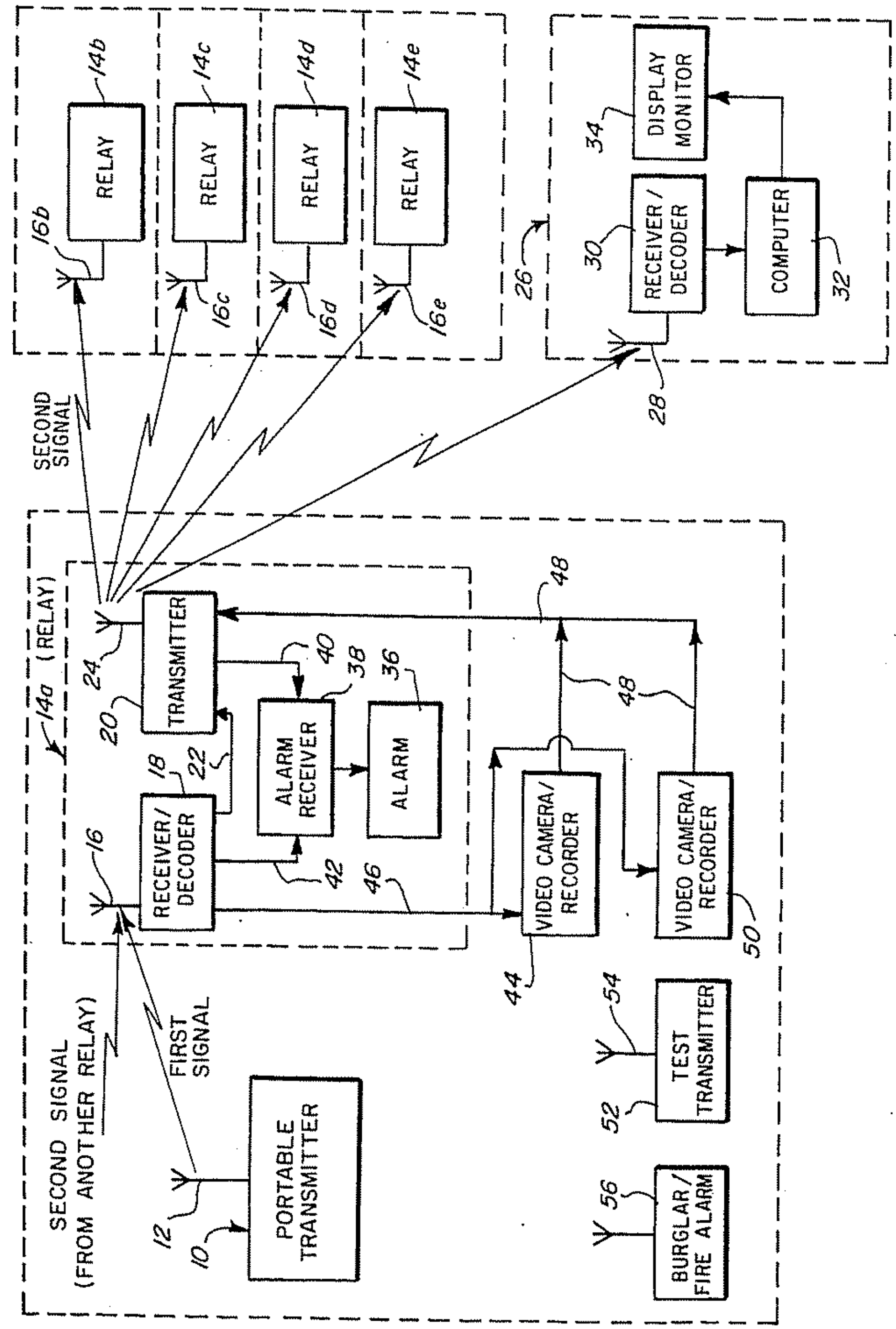


FIG. 1


RELAY
RELAY
RELAY
RELAY
SECOND SIGNAL
RECEIVER / DECODER
COMPUTER
DISPLAY MONITOR
14a (RELAY)
TRANSMITTER
RECEIVER/ DECODER
ALARM RECEIVER
ALARM
VIDEO CAMERA/ RECORDER
VIDEO CAMERA/ RECORDER
SECOND SIGNAL (FROM ANOTHER RELAY)
FIRST SIGNAL
PORTABLE TRANSMITTER
TEST TRANSMITTER
BURGLAR / FIRE ALARM

SECURITY AND COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

There is a growing need in the world as we find it for both improved security and for improved communication capability. In many areas of the cities, in public transportation, on the highways, in large buildings after business hours, and in many other situations and areas, there is the occasional need to give an urgent alarm.

Because of the lack of this capability in areas such as deserted streets after dark and public transportation, such areas have become prime spots for the activities of violent criminals. If there were a system which made it possible for individuals to give an instant alarm, criminal activity would be greatly suppressed.

Furthermore, the need for signaling and communication goes beyond criminal activity. A security and communication net which covers a large area could be used in a multitude of ways for safety, as well as for other priority or urgent communication.

DESCRIPTION OF THE INVENTION

By this invention, a security and communication system is provided in which at least one portable radio frequency transmitter has means for sending a first signal including a first individual identification code to identify the portable transmitter, when actuated by the user. Preferably, it is contemplated for the portable radio frequency transmitters to be sized for personal portability, for example being of the size of a cigarette pack, a wrist watch, or a necklace pendant so that a large number of people will carry individual radio frequency transmitters, having separate, first individual identification codes, in their everyday business. The term "radio frequency" is not intended to be a limiting term, and may include any portion of the electromagnetic spectrum suitable for transmission of information over distances.

A plurality of radio frequency relays are also provided, each being positioned in a predetermined location, unlike the portable radio frequency transmitter. The radio frequency relays have means for receiving a first signal from any of the portable transmitters. Upon receiving such signal, a relay will immediately transmit a second signal including the first identification code from the first signal and a second identification code to identify the individual relay that is transmitting the second signal.

The receiving station for the second signal from a radio frequency relay may be central means for receiving the signal such as a police facility or the like, and/or the other local radio frequency relays may be adapted to receive the second signal and to report its receipt by means of an audio or visual signal.

The radio frequency relays are preferably spread out and spaced over an area in their positions so that no more than relatively few of the relays can be simultaneously actuated by receiving the first signal from the same portable transmitter. Preferably, the positioning is such that only one relay will pick up a signal from any one portable transmitter, although in some circumstances two or three relays may report the signal.

The radio frequency relays may be located around a city area, a public garage, in separate cars of mass transit or other trains, or in any other situation desired where an alarm may need to be given. Individuals come and go throughout the area, carrying their portable radio frequency transmitters in their pocket or purse, or as a necklace pendant, or any other desired way. In the event of an urgent situation arising, for example a mugging, a fire, or whatever it may be, one or more individuals seeing the situation activate their radio frequency transmitters to send out a first signal including the first individual identification code identifying the individual transmitter. A radio frequency relay receives the first signal, and immediately retransmits a second signal including the first identification code to identify the individual transmitter, plus a second identification code to identify the individual relay that is transmitting the second signal. This second signal may of course be as powerful a radio signal as necessary, or its second signal may travel over telephone lines or the like, since the relays are stationary and may be as large as necessary to effectively perform their function. The second signals may be transmitted to central means for receiving the signals, such as a police or security station, which may be equipped with microprocessor means for identifying and immediately displaying the location of any relay or relays activated, and also the identity of the transmitter sending the signal.

Thus, the location of the relay is immediately known, indicating the approximate location of the transmitter which sent the signal. At the same time, the identity of the transmitter is known, so that the owners are induced to exercise a certain amount of responsibility. Police or other agencies can be immediately sent to the scene.

Alternately or additionally, the radio frequency relays may each carry audible alarm means, plus control means to cause at least one relay adjacent a relay that receives a first signal to produce an audible alarm, while causing the relay directly receiving the first signal to remain silent. Thus, this arrangement serves as a silent alarm, where no alarm is given in the immediate vicinity of the person giving the alarm, but adjacent relays scattered around the area are actuated to alert people in the neighborhood of the difficulty.

Thus, if the radio frequency relays are in separate railroad or rapid transit cars, an individual seeing a crime in one of the cars will actuate his portable transmitter, with no alarm being set off in the car. However, in adjacent railroad or rapid transit cars the alarm will be set off. Thus, the motormen can signal for the police, or if police are present on the train, they will be immediately alerted.

Additionally, means may be provided to cause the audible alarm to identify the relay directly receiving the first signal. This can be done by a prearranged code of beeps, visual readout, or an electronic voice system governed by microprocessors, making use of technology which is currently well-known. Thus, the exact railroad car or other location can be identified.

Similarly, groups of shopkeepers or homeowners in city can be immediately alerted of a crisis in a neighboring shop or home, with radio frequency relays in each of their stores or homes sounding the audible alarm plus information as to the location of the alarm.

As a further possibility for the security and communication system of this invention, video recorder means are provided to monitor various preselected sites. Means are also provided, conventional to the art, for actuating the video recorder means when a radio frequency relay receives a first signal from a portable radio frequency transmitter. The video recorder may carry video tape to store what it records of the events that set

off the alarm, or it may be one of a large number of video recorders which communicate with a monitoring screen in the police station or security section. It may be that there are so many video recorders that they are difficult to monitor, so the recorders do not record unless an alarm is sensed by a radio frequency relay. Then, the local video recorder is turned on, and the signal automatically sent to the central station so that the police or other personnel have a visual view of the situation simultaneously with the alarm itself.

In some circumstances, it may be that a large number of People carrying portable radio frequency transmitters may observe a crisis taking place at once. They may all reach for their transmitters and activate them in a period of a few seconds. Accordingly, the relays may have jamming detector means to filter out all competing first signals except for one signal (typically the strongest signal) in the event of simultaneous transmission of several first signals, whereby the relay transmits the first identification code of that one first signal.

As a further modification, the first signal may be in the form of a coded pulse of the duration of a fraction of a second (typically one-thousandth of a second or so). The jamming detector means may be modified and the relays may have memory means to receive and to store a plurality of differing first signals, since each of them, lasting only a thousandth of a second or so, may be separately received without interference from the other pulses in the usual circumstance, since ideally about 1,000 differing first signals could be received per second.

Sequential transmission means are then provided to cause the relays to sequentially transmit in the second signal the various first identification codes of the stored first signals so that, after the second signal gives notice of the alarm, all or most of the signals of the individual portable radio frequency transmitters may be individually identified, typically to the central means for receiving the signals from the relays for storage in microprocessor means and subsequent readout or printout for a permanent record.

The jamming detector may also activate its relay to send an alarm signal if a strong jamming signal on the proper frequency is received. This could thwart a criminal attempt to disable the system.

As a further modification, a transmitter may be provided for test response of the radio frequency relays. When the particular identifying number of the test transmitter is received by each relay, it would be programmed not to send an alarm, but to respond in an appropriate manner to indicate nominal functioning.

Likewise, a burglar or fire alarm may be connected locally to any of the radio frequency relays as may be desired.

As a further alternative, passengers on a airplane may be equipped with radio frequency transmitters with a radio frequency relay positioned in the pilot's cockpit. This can provide early warning of a hijacking or other difficulty.

Also vehicles, money bags, and the like may carry the radio frequency transmitters of this invention, each with their own identification code so that the vehicle or other item may be immediately identified at the central station via signals received from the relays. These particular radio frequency transmitters may be concealed in the vehicle or other item, and may be individually activatable by a strong coded signal broadcast throughout the area, which could be broadcast upon loss of the vehicle or other item. Alternatively, they may be manually activated. Once activated, the radio frequency transmitter continues its transmission so that the stolen article can be traced as it moves, by the particular relays that it activates.

It is understood that the state of the electronics art is advanced to a sufficient degree so that the various functions outlined herein can be readily embodied in electronic circuitry by those having normal skill in the art.

DESCRIPTION OF THE DRAWING

In the drawing, FIG. 1 is a diagramatic view of a security and communication system in accordance with this invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring to the drawing, a security and communication system is illustrated which comprises at least one portable radio frequency transmitter **10**.

Portable transmitter **10** may be carried by a person, and may be the size and shape of a cigarette pack, a wrist watch, or a necklace pendant, for example. The ET-1 linear alert receiver, manufactured by Linear Electronics of Inglewood, Calif. illustrates the general type of technology that may be used for transmitter **10**.

Transmitter **10**, when activated by the wearer, transmits through antenna **12** a radio frequency signal which includes an identification code, so that the particular transmitter which is sending the signal can be identified. The identification code may be as long and complex as necessary to accommodate whatever number of individual transmitters are in the system, so that each individual transmitter can be identified from its transmission.

A series of radio frequency relays **14***a, b, c, d,* and *e* are positioned respectively in predetermined locations. For example, radio frequency relays may be positioned on street corners, in individual railroad cars, in halls of buildings, or the like. Each relay **14***a–e* may be of the specific design as shown for relay **14***a*, having an antenna **16** tuned to receive signals emitted by antenna **12** of each transmitter **10**. Typically, relays **14***a–e* are spread out to a degree sufficient that only one relay will be in a position to sense an individual signal from a transmitter **10**, or at the most only 2 or 3 relays.

Radio frequency relays may be of a design similar to the DX-12 receiver, also manufactured by Linear Electronics, modified as desired in ways clear to those skilled in the art to accomplish the purposes of this invention.

The signal from transmitter **10** received by antenna **16** is picked up by receiver decoder means **18** which may be of conventional design to decode the signal and to send it through conductor **22** to transmitter encoder **20**. From there, a signal is dispatched through antenna **24** which incorporates the identification code received from transmitter **10**, and also includes the individual identification code of the specific radio frequency relay which received the signal from transmitter **10**. From antenna **24**, or, alternatively through a telephone line or the like. the signal may be transmitted to central receiving station **26**, which may be located at a police station, a security room, or the like. Alternatively or additionally, the signal from antenna **24** may be receivably by at least some of other relays **14***b*–**14***e*. The signal from antenna **24** may be distinguishable from the signal from antenna **12**, for example by use of a different frequency.

The signal is thus received by antenna **28** of central receiving station **26**, and at that point it is conveyed to receiver-decoder **30**. A signal is then sent to computer or microprocessor **32** for logging the date, the time, and the various first and second identification codes received in the signal. From there, the critical data is displayed on display monitor **34**, including the exact location of relay **14***a*, which is stored in the computer memory in correlation with its second identification code, relay **14***a* being the relay which received the signal from transmitter **10**.

Thus, the authorities at central receiving station **26** are immediately alerted to the fact that transmitter **10** of known identification has sent a signal from the vicinity of relay **14***a*. They can then take appropriate action.

As an added desired feature, each of relays **14***a–e* may contain alarm means **36**, which may be audio, visual, or both as desired. The actuation of alarm **36** controlled by receiver **38** which, in turn, may be actuated by transmitter **20** via conductor **40**. However, a connection between receiver-decoder **18** and alarm **38** is also provided by conductor **42**. Alarm receiver **38** carries appropriate and conventional circuitry so that if a signal has been received from receiver **18** through conductor **42**, for example within some predetermined, prior time indicating that the signal from transmitter **10** was directly received by receiver-decoder **18**, alarm receiver **38** will not actuate alarm **36** despite the signal from transmitter **20** through conductor **40**. Signals from other relays may also be distinguishable by use of a different frequency or code, so that such signals do not activate receiver-decoder **18** to block actuation of alarm **36**.

Thus, in this circumstance, relay **14***a* will not sound alarm **36**. However, the signal from transmitter **20** may be received by nearby relays **14***b–e* which may be of substantially identical construction to relay **14***a*. These relays **14***b*–**14***e* may be too far away to pick-up the signal from transmitter **10**. Thus their respective alarms will be actuated, so that the alert will be sounded in an area adjacent to the present location of the transmitter **10**, but not exactly at the location of transmitter **10**. Thus criminals may not be alerted to the fact that the alert has been sounded.

Additionally, a video camera **44**, positioned to record a predetermined view, may be connected to receiver-decoder **18** through conductor **46**, so that when a signal is received by receiver-decoder, a corresponding signal is passed through conductor **46** to actuate video camera **44** for a predetermined length of time. If desired, the video signal may pass through conductor **48** to transmitter **20**, or another transmitter, if desired, for immediate transmission to central station **26**. A similar set-up may be provided for a second video camera **50** pointing in another direction, if desired.

It should be understood that central station **26** is not necessarily physically central within the respective transmitters, but is simply central in terms of the flow of signals.

Test transmitter **52** may carry antenna **54** to transmit radio signals which may be picked up by relays **14***a–e*. The test transmitter may have an identification code, and each receiver-decoder **18** may carry a microprocessor function which is actuated by that identification code and no other, to inhibit the sounding of an alarm. Instead, a different signal may be sent through conductor **22** to transmitter encoder **20** which characterizes proper test operation of each relay **14***a–e* without sounding an alarm.

Additionally, radio operated burglar or fire alarms **56** may be provided as well, to be actuated by receiving a signal from any of relays **14***a*–**14***e*.

Thus, the security and communication system disclosed herein can provide immediate indication of troubles over a wide area, including the location of the trouble and the identification of the person sounding the alarm.

The above has been offered for illustrative purposes only, and is not intended to limit the scope of the invention of this application, which is as defined in the claims below.

That which is claimed is:

1. A security and communication system, which comprises:

at least one portable radio frequency transmitter having means for sending a first signal including a first individual identification code to identify the portable transmitter, when actuated by the user;

a plurality of radio frequency relays, each positioned in a predetermined location and having means for receiving said first signal and immediately transmitting a second signal including said first identification code and a second identification code to identify the individual relay that is transmitting the second signal;

each of said relays having alarm means for actuation in response to receipt of said second signal from another relay; each of said relays also having means for inhibiting its alarm in response to receipt of said first signal, whereby the relay directly receiving said first signal has its alarm inhibited while the alarm means of the other relays are not inhibited.

2. The system of claim 1 in which said radio frequency relays are spread out in their positions so that only no more than relatively few of said plurality of relays can be simultaneously actuated by receiving said first signal from the same portable transmitter, whereby the general location of the signaling portable transmitter can be established.

3. The system of claim 2 including central means including microprocessor means for identifying and reporting the location of any said relay activated and the identity of the transmitter sending the signal.

4. The system of claim 1 including a plurality of said radio frequency transmitters, each of a size small enough to be carryable by individual users.

5. The system of claim 1 in which means are provided to cause said alarm means to identify the relay directly receiving the first signal.

6. The system of claim 1 including video recorder means, and means for actuating said video recorder means when a radio frequency relay receives a first signal.

7. The system of claim 1 in which said first signal is in the form of a coded pulse of the duration of a fraction of a second, and said relays have memory means to receive and to store a plurality of differing first signals, and sequential transmission means to cause said relays to sequentially transmit in the second signal the various first identification codes of the stored first signals.

8. A security and communication system which comprises:

a plurality of radio frequency transmitters, each of a size small enough to be carryable by individual users, and having means for sending a first signal including a first individual identification code to

identify the portable transmitter, when actuated by the user;

a plurality of radio frequency relays, each positioned in a predetermined location and having means for receiving said first signal and immediately transmitting a second signal including said first identification code and a second identification code to identify the individual relay that is transmitting the second signal;

said radio frequency relays being spread out in their positions so that no more than relatively few of said plurality of relays can be simultaneously actuated by receiving said first signal from the same portable transmitter, whereby the general location of the signaling portable transmitter can be established;

each of said relays having alarm means for actuation in response to receipt of said second signal from another relay; each of said relays also having means for inhibiting its alarm in response to receipt of said first signal, whereby the relay directly receiving said first signal has its alarm inhibited while the alarm means of the other relays are not inhibited; and

central means for receiving the signals form said radio frequency relays.

9. The system of claim **8** in which said first signal is in the form of a coded pulse of the duration of a fraction of a second, and said relays have memory means to receive and to store a plurality of differing first signals, and sequential transmission means to cause said relays to sequentially transmit in the second signal the various first identification codes of the stored first signals.

10. The system of claim **9** in which said central means includes microprocessor means for identifying and reporting the location of any said relay activated and the identity of the transmitter sending the signal.

11. The system of claim **8** in which means are provided to cause said audible alarm to identify the relay directly receiving the first signal.

12. The system of claim **11** including video recorder means, and means for actuating said video recorder means when a radio frequency relay receives a first signal.

13. A security and communication system, which comprises:

at least one portable radio frequency transmitter having means for sending a first signal including a first individual identification code to identify the portable transmitter, when actuated by the user;

a plurality of radio frequency relays, each positioned in a predetermined location and having means for receiving said first signal and immediately transmitting a second signal including said first identification code and a second identification code to identify the individual relay that is transmitting the second signal, said radio frequency relays being spread out in their positions so that only no more than relatively few of said plurality of relays can be simultaneously actuated by receiving said first signal from the same portable transmitter, whereby the general location of the signaling portable transmitter can be established;

each of said relays having alarm means for actuation in response to receipt of said second signal from another relay; each of said relays also having means for inhibiting its alarm in response to receipt of said first signal, whereby the relay directly receiving said first signal has its alarm inhibited while the alarm means of the other relays are not inhibited;

14. The system of claim **13** in which means are provided to cause said audible alarm to identify the relay directly receiving the first signal.

15. The system of claim **14** including video recorder means, and means for actuating said video recorder means when a radio frequency relays receives a first signal.

16. In a security and communciation syste, a plurality of radio frequendy relays, each positioned in a predetermined location and having means for receiving a first signal and immediately transmitting a second signal plus an identification code to identify the individual relay that is transmitting the second signal, said radio frequency relays being spread out in their positions so that only no more than relatively few of said plurality of relays can be simultaneously actuated by receiving a first signal from a portable transmitter, whereby the general location of the signaling portable transmitter can be established; each of said relays having alarm means for actuation in response to receipt of said second signal from another relay; each of said relay also having means for inhibiting its alarm in response to receipt of said first signal, whereby the relay directly receiving said first signal has its alarm inhibited while the alarm means of the other relays are not inhibited.

17. The system of claim **16** including control means for receiving signals from radio frequency relays, said control means including microprocessor means for identifying and reporting the location of any said relay activated.

18. The system of claim **16** in which means are provided to cause said alarm means to identify the relay directly receiving the first signal.

19. The system of claim **16** including video recorder means, and means for actuating said video recorder means when a radio frequency relay receives a first signal.

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